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The International Conference on the Peaceful Uses of Atomic Energy

By unanimous vote, the General Assembly of the United Nations decided last December that an international technical conference of governments should be held, under the auspices of the United Nations, to explore means of developing the peaceful uses of atomic energy through international co-operation. This decision formed part of an Assembly resolution adopted on the basis of an "atoms-for-peace" proposal originally sponsored by seven members—Australia, Belgium, Canada, France, the Union of South Africa, the United Kingdom, and the United States. The General Assembly also decided that all States Members of the United Nations or of the specialized agencies should be invited to participate in the Conference.

The Conference, which is being held at Geneva between the 8th and 20th of August, 1955, will be scientific and non-political in character. It will not pass resolutions nor will it approve any recommendations. It will bring together eminent scientists and other experts from all parts of the world to exchange information on the peaceful uses of atomic energy.

Under the rules of procedure for the Conference, each State invited and each specialized agency may send up to five representatives, including, as far as possible, "individual experts competent in the atomic-energy field." However, the representatives may be accompanied by as many advisers as they may need.

A large number of scientific papers will be presented. In addition to plenary sessions discussing power needs and power supplies in the world, the Conference will consist of sessions for five sections dealing with reactors, reactor physics, reactor chemistry and metallurgy, biological and medical aspects, and applications of radioisotopes to research and industrial problems.

All meetings will be public, with simultaneous interpretation into the four official languages of the Conference—English, French, Russian, and Spanish. It is planned to hold three simultaneous meetings morning and afternoon.

With the large number of contributions anticipated, it is obvious that there cannot be sufficient time for presentation of all the important papers submitted. Therefore, a selection of those to be read to the Conference will be made by a panel of scientists designated by the United Nations Secretary-General on the advice of the Advisory Committee. However, papers not presented orally will be considered as part of the Conference, provided that they conform to its purposes, and will be included in the published proceedings. The rules of procedure provide for discussion in the plenary and section meetings of the papers presented.

Among the main concerns of the Conference will be the production of power through nuclear reactors, and the use of radioactive isotopes in medicine, biology, agriculture, and industry. Thus, for instance, in the sessions devoted to the need for a new power source, survey papers will be presented regarding the estimated world requirements during the next 25 to 50 years, and alternative power sources. In this connection, it should be understood that, insofar as nuclear power is concerned, all operations projected at present will utilize fission reactions, whereby the splitting of heavy nuclei, such as uranium or plutonium, releases energy. However, some consideration might also be given to the possibility of obtaining useful power from fusion reactions, in which energy is released from the combination of very light nuclei, such as hydrogen, to form heavier ones. Another important consideration in assessing means by which future power needs may be met is that the efficiency of coal- and oil-burning and hydroelectric plants has steadily increased, and is likely to continue to improve.

This session will also bring out the range of power and heat problems confronting various individual countries over the next 50 years and will indicate possible solutions to these problems. An effort will be made to give all estimates of cost and demand on a similar basis, so that they may be easily compared, to determine where the needs are the greatest. Each nation has been invited to furnish all available data, and the Conference Organization will prepare a summary of the papers submitted. In addition, typical papers dealing with some characteristic regions, or with specific conditions of industrial development, will be selected for presentation. Consideration will be given to the economic significance of nuclear power in non-industrialized countries, in countries which are making the transition from an agricultural to an industrial economy, and in already industrialized countries.

A special session will be devoted to the role of nuclear energy and will include papers on the maximum plausible role which nuclear energy can play as a source of energy during the next 25 to 50 years, and on the natural occurrence of uranium and thorium. With regard to the latter survey, the use of nuclear energy, as now contemplated, depends directly on uranium and thorium. To gauge the extent to which nuclear energy can meet the world's future power needs, it is essential to estimate as accurately as possible the availability of these essential raw materials. Such data may help determine the course that nuclear developments should follow. For example, U-233, which is a fissionable material and can be used like U-235 as a nuclear fuel, can be made from thorium in a reactor. If thorium should become more readily available than uranium, then it might prove advisable to extend research and study on methods of using thorium. With such considerations in mind, each nation has been invited to furnish all available data on the extent to which uranium and thorium are known to be available, so that the Conference may assess the situation.

Still another important paper will deal with the economics of nuclear power. With no actual experience in constructing large-scale nuclear power plants, it is not possible to assess accurately the economics of nuclear power, particularly since there are so many features which nuclear power plants require, not needed in conventional power plants. Among these may be mentioned the structure of the reactor itself, radiation shields, unconventional pumps, disposal of radioactive wastes, radiation measuring instruments, means of processing and recycling used fuel, etc. However, it is possible to make estimates on other factors which enter into the cost of nuclear power, the fuel costs, and the operating costs for a nuclear power system.

A series of papers will also be presented at these plenary sessions in connection with the building of a nuclear-energy enterprise, the health and safety aspects of nuclear energy, the production and uses of isotopes, and problems relating to large quantities of radioactive substances.

Insofar as reactors are concerned, special sessions will include papers dealing with research reactors, power-reactor prototypes, fuel cycles, and the technical principles of reactors, with detailed descriptions of specific embodiments.

Technology sessions will include papers on methods of prospecting for uranium and thorium, the chemical treatment of low-grade ores and ore concentrates of uranium and thorium, and the production of uranium and thorium metal from high-grade ores and concentrates. In addition, special sessions will deal with such subjects as the production technology of various materials, the chemical aspects of nuclear reactors, the storage and separation of fission products, the fabrication of fuel elements (including the canning problem), liquid-metals technology, and the problems of waste treatment and disposal. Other sessions will include papers on the chemistry of the fission products, heavy-element chemistry, and radiation chemistry and radiation damage.

In the biological and medical sessions, the application of nuclear energy in the solution of special problems in biomedical research and public health will be discussed, together with indications of the genetic effects of radiation, and radiation injury and protection. Other sessions will be devoted to such important subjects as the utilization of nuclear energy for solving special problems in agriculture and silviculture (including plant genetics and crop improvement, and pests and diseases), and public-health aspects attendant on the large-scale utilization of atomic energy.

In addition, sessions will deal with the application of radioisotopes to research and industrial problems and will include papers on the use of tracers in general research, the application of isotopes in process and quality control, the industrial utilization of fission products, and developments in dosimetry, instrumentation, and remote control.

With regard to the closing plenary session, it is at present anticipated that this will be devoted to summarizing the important results of the entire Conference. While the exact form the summary will take has not yet been decided, there are certain topics which the Advisory Committee to the Secretary-General has decided to include as specific agenda items for this closing plenary session. These topics include the possible role of thorium in nuclear energy, the important problem of training technical personnel for nuclear-energy work, and a summary of communications from various States participating in the Conference, concerning measures for assistance to other countries in the use of atomic energy for peaceful purposes.

As a special feature of the Conference there will be a series of evening lectures on scientific subjects associated with the field of nuclear energy. These lectures will be given by scientists of international repute.

Finally, in conjunction with the Conference, there will be an International Exhibition dealing with the peaceful uses of atomic energy, in which the United Kingdom will be strongly represented.

The Conference proceedings and a selection of items from the Exhibition will be reviewed in this Journal at a later date.

HOLLAND

Electronic Equipment for the Continuous Monitoring of Steam Turbines

By C. VAN BASEL, H. J. LINDENHOVIUS, and G. W. VAN SANTEN. (From *Philips Technical Review*, Vol. 17, August 1955, pp. 59-66, 14 illustrations.)

IN dealing with continuous control of the running conditions of steam turbines, the first quantity to be considered is the measurement of the vibration amplitude in the bearings. This measurement provides information regarding any unbalance of the rotor system, any play in the bearings, or "fouling." A timely indication of any excessive vibration amplitude may prevent enormous damage.

A second quantity of importance is the change in length of the shaft relative to the casing. For every variation in the steam pressure the quantity of heat supplied per second is changing and together with it the temperature of rotor and casing. Since the rotor possesses a smaller heat capacity and a greater coefficient of thermal conduction than the stationary, thick-walled casing, the former suffers more rapid changes in temperature and therefore expands more quickly. Continuous monitoring of the relative change in length of the shaft with respect to the casing is therefore most desirable. In addition, apart from this relative change in length, it is often desirable to measure the absolute change in length of the casing.

The fourth quantity to be measured is the eccentricity of the shaft. Particularly during running-up and slowing-down of the turbine it is possible that heating or cooling along the circumference of the rotor does not take place quite uniformly. The accompanying irregularity of expansion or contraction is manifested in a bending of the shaft. For this reason eccentricity should also be checked, particularly at low rotor speeds.

Among other methods for measuring the above-mentioned quantities, electronic methods are particularly attractive, inasmuch as they not only provide a means of power amplification, with a consequent high degree of sensitivity, but also, by reason of the fact that the action of electronic amplifiers is virtually free from inertia, they make it possible to measure rapidly varying quantities. Other advantages are that they permit reading or recording to be effected at a considerable distance from the actual measuring point, and that the properties of electrical circuits are easily adaptable to the circumstances prevailing in the turbine. Furthermore, they permit relative displacement and eccentricity to be measured without any mechanical contact with the object, so that there is no wear on the detecting element and no risk, in case of breakdown, of possible interference with the turbine itself.

MONITORING OF SHAFT-BEARING VIBRATIONS

The amplitude of bearing vibrations can be measured with the aid of an electrodynamic vibration pick-up of the type shown in cross-section in Fig. 1. The main components of this pick-up are the housing H surrounding the rigidly fixed permanent magnet M, and the spring membranes V, connected by a central pin and carrying the output coil S_1 (with connection contact C) and the damping coil S_2.

The housing H is fixed on the cap of the bearing in question, and so follows its every variation. The spring-mounted coils S_1 and S_2, on the other hand, follow

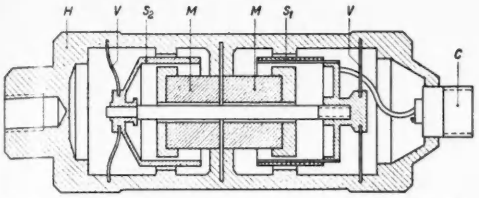

Fig. 1. **Cross-section of an electrodynamic vibration pick-up.**

these motions to a far less degree and hardly at all if the frequency is sufficiently high. The magnet M connected to the housing moves relative to the more or less stationary coils and induces in the latter a voltage proportional to the velocity of the displacement. Coil S_2 is short-circuited; this provides the "half-critical" damping (i.e., a damping half as great as the critical damping) required for a favourable frequency-response curve. Coil S_1 is connected to an output cable.

In order to obtain a voltage which is not proportional to the velocity of the displacement, but to the displacement itself, the output voltage of the pick-up has to be integrated over the time. This is easily effected by means of a single RC-network. By means of a rotary switch a maximum of 12 pick-ups can be successively connected to this integrating RC-network. The network is followed by an amplifier, a rectifier, and a smoothing filter. The direct voltage thus obtained is a measure of the amplitude of the vibrations and may be recorded by means of a recording millivoltmeter. In practice, it has been found most suitable to select such a sensitivity that a vibration amplitude of 50 μ corresponds to full deflection of the pointer. The recorder is provided with an adjustable contact which operates an alarm installation as soon as one of the vibration amplitudes exceeds the preset value.

The proper functioning of the equipment may easily be checked at any desired moment by means of an accurately adjustable alternating voltage derived from a transformer connected to the mains.

Relative Change in Length of Shaft

The relative change in length of the shaft is measured with an inductive displacement pick-up. This instrument (Fig. 2) consists of an armature A of a magnetic material situated between two U-shaped yokes J of laminated nicalloy. Each of the yokes is provided with a coil. The two coils, L_1 and L_2, of an equal number of turns, together with two equal resistances, R_1 and R_2, form a bridge circuit. One diagonal is fed, *via* a transformer T_1, from a valve oscillator (frequency 500 cps). The primary coil of an output transformer T_2 is connected to the other diagonal.

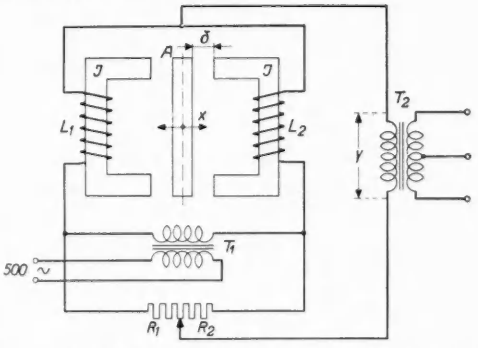

Fig. 2. **Schematic diagram of an inductive displacement pick-up.**

When the armature is situated exactly midway between the two yokes, the self-inductances of the two coils are equally great and no voltage appears across the primary of transformer T_2. When the yoke is displaced to the right a distance x, the self-inductance of the right-hand coil increases, since here the air gap δ has become smaller, whereas the self-inductance of the left-hand coil decreases. The bridge circuit is now no longer balanced, and a voltage y is produced across T_2 which is nearly proportional to the displacement x over a wide range of values of the air gap δ. If the armature were moved the same distance x to the left, then an equally large voltage would be produced across T_2—this time, however, in opposite phase. In order to distinguish between movement to the right and to the left, it is necessary to identify the phase, for which purpose a phase-sensitive detecting circuit is used.

In using a pick-up of this type for measuring the change in shaft length of a turbine, a nickel-iron-alloy disc, which has the same function as armature A, is fitted on to the shaft, and the two yokes J are rigidly connected to the casing. A minor complication in connection with this equipment lies in the fact that the turbo-generator is surrounded by a magnetic and an electric field, both of which may impair measurements. The pick-up, therefore, should be carefully screened, magnetically as well as electrically. For this purpose it is housed inside a thick-walled steel box lined with mu-metal. Moreover, the coils are wound in such directions that the influence of an external magnetic field is reduced to a minimum.

A second complication arises from the fact that the disc rotates within the magnetic field of the coils, so that eddy currents are generated in the disc, giving rise to amplitude and phase errors. To keep these errors as small as possible, the disc, as already stated, is made of a nickel-iron alloy with a high resistivity. Use of this material has the added advantage that it is easily machinable.

The air gap on either side of the disc is 10 mm. The maximum displacement that can be measured is 5 mm to either side.

Absolute Change in Length of the Casing

The absolute change in length of the casing is also measured by means of a displacement pick-up, in which the armature is connected to the casing and the yokes to the foundation. Since here the displacements to be measured are fairly large (up to 20 mm), very wide air gaps would be required to obtain a linear scale, necessitating yokes of very great dimensions. This has been avoided by giving the armature A a wedge-like shape (Fig. 3), such that an axial displacement is converted into a lateral displacement 50 times smaller, the latter being measured in the manner already described. With this (somewhat unusual) reduction of sensitivity, the air gaps δ can be confined to 5 mm, so that yokes of

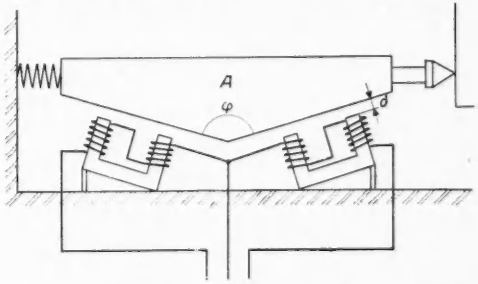

Fig. 3. **Schematic diagram of a displacement pick-up for measuring absolute change in length of a casing.**
In this diagram, the angle φ, actually about 178 deg, is shown smaller for the sake of clarity.

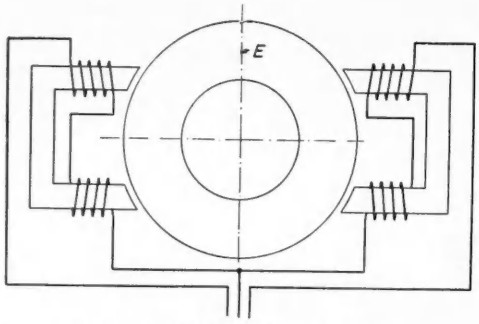

Fig. 4. **Inductive displacement pick-up in a form suitable for measuring shaft eccentricity.**

normal dimensions can be used. This construction makes it possible to measure displacements up to 50 mm to either side.

Eccentricity

Measurement of eccentricity is also effected by means of an inductive displacement pick-up, the construction of which is shown schematically in Fig. 4. The armature consists of a disc E of the same nickel-iron alloy as that used for measuring the relative change in shaft length, as previously described.

Any eccentricity of the shaft is manifested by the fact that the centre of disc E does not remain stationary, but describes a circle of, say, radius e. Hence, the distance from the circumference of the disc to the yokes changes periodically with an amplitude e.

In the two previous cases gradually changing quantities were involved ; here, however, it is necessary to deal with a dynamic phenomenon, as the distance to be measured changes periodically with a frequency equal to the rotational speed of the shaft. The output voltage of the bridge, therefore, consists of a signal of 500 cps modulated with the (far lower) frequency of the shaft. This output voltage is applied *via* a demodulator to a recording measuring instrument. As long as the rotational speed is very small (below about 60 rpm), the pointer of the recording meter closely follows the distance variations. As the rotor speed increases, the recorded amplitude decreases, until finally the pointer does not fluctuate at all, but indicates only the average position of the centre of the disc. This information, too, is valuable, since it is an indication regarding the thickness of the oil film in the bearings.

If it is desired, however, to measure the eccentricity at high speeds as well, then, just as when measuring the vibration amplitude, the demodulated output voltage has to be rectified and smoothed, after which the direct voltage thus obtained can be recorded.

The air gap between disc and yokes is adjusted to 2·5 mm ; an eccentricity of 0·5 mm produces full-scale deflection.

Electrical Circuit

Fig. 5 shows a block diagram of the circuit used for length and eccentricity measurements. A rotary switch S, driven by a small electric motor, makes it possible to connect alternately six inductive pick-ups D_1-D_6. The sensitivity and the zero point of each of these pick-ups is adjustable by means of its two potentiometers P incorporated in the apparatus. A calibration pick-up D_0 is also incorporated.

The demodulation of the output voltage of the bridge takes place in the phase-sensitive detector *Dem*. The voltage thus obtained is smoothed of the 500-cps component from the oscillator O by a filter F_1, and the remaining low-frequency voltage is applied to a recording instrument mV. Only for measuring eccentricity at high speeds is the signal subjected to a subsequent rectification and smoothing, as mentioned above. This rectifier *Det* may be switched on or off, as required ; sometimes, the switch is operated by a relay, which is automatically energized as soon as the rotor speed exceeds a certain value (e.g., 48 rpm, corresponding to 0·8 cps). The amplifier A, the detector *Det*, and the smoothing filter for shaft frequency F_2 function only for measuring eccentricity at rotor speeds above 48 rpm.

The functioning of the equipment can at all times be checked by means of one or more standard pick-ups, of identical construction to the pick-ups mentioned above, but provided with a micrometer screw, by means of which the armature can be displaced over accurately adjustable and known distances.

Those parts of the equipment which are sensitive to fluctuations of the supply voltage are fed from a stabilized voltage supply, so that mains-voltage fluctuations cannot impair the results.

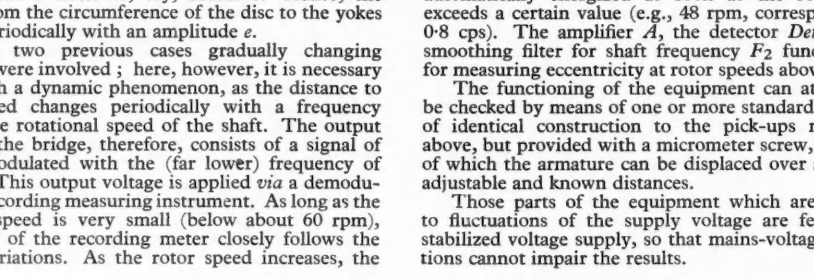

Fig. 5. **Simplified block diagram of the electrical circuit for monitoring changes in length and eccentricity.**

A Pilot-Model Nuclear Power Plant

By W. R. GALL. (From *Mechanical Engineering*, Vol. 77, No. 7, July 1955, pp. 575-580, 7 illustrations.)

Known as the Homogeneous Reactor Experiment, a nuclear pilot plant for the production of electric power has been designed, constructed, and operated by the Oak Ridge National Laboratory over a four-year period. Details of the design of major items of equipment and the shield are included in this paper.

IN 1950 the Oak Ridge National Laboratory undertook the task of designing, building, and operating a pilot-model liquid-fuel nuclear reactor, the Homogeneous Reactor Experiment. The purpose of this plant was to investigate the chemical and nuclear feasibility of maintaining a nuclear chain reaction in an aqueous solution at a temperature sufficiently high for the production of electric power from the thermal energy released.

Some of the problems anticipated in the design were as follows :—

(1) Radiation decomposes the water molecules into hydrogen and oxygen. Would the generation of these gas bubbles within the liquid core cause nuclear instability ?

(2) How could the hydrogen and oxygen produced by decomposition of water be recombined and returned to the system ? It was estimated that the decomposition rate would be sufficient to convert all the water in the fuel solution to gas within a few hours.

(3) It was expected that the reactor would have self-regulating properties. Would it be self-regulating, or would a fast-acting control system be required ?

(4) How would gaseous fission products be disposed ?

(5) How would leakage be kept low enough to prevent serious contamination and loss of valuable materials ? The radioactivity of the fuel solution would be approximately 30 curies of gamma radiation per cubic centimetre. Hence, permissible leak rates were of the order of 0·1 cc of helium per 24 hr to 1 micron absolute pressure.

DESCRIPTION OF SYSTEM

Some of the basic design data for this reactor are as follows :—

Design power level [kW of heat]	1000
Net electric power [kW]	120
Auxiliary power consumption [kW]	30
Fuel composition	UO_2SO_4 in H_2O
Outlet temperature [°F]	482
Inlet temperature [°F]	410
Operating pressure [psia]	1000
Flow rate through reactor [gpm]	100
Steam conditions, full load [psia sat.]	200
Steam conditions, no load [psia]	360

With regard to the reactor vessels, nuclear energy is released in the reactor core, a stainless-steel spherical vessel, 18 in. in diameter, through which the solution is pumped with vortex flow. The core vessel is surrounded by a heavy-water reflector, approximately 10 in. thick, which is kept at the same pressure as the core. Thus, only the outer vessel is designed for the high pressure. The core vessel is suspended inside the pressure vessel by its inlet and outlet pipes from a flat bolted head. Also mounted on the head are three control-element drive mechanisms and a steam-heated pressurizer for the core system. The control elements consist of plates, containing neutron-absorbing material, which may be lowered into positions against the outside of the core vessel, thus shielding the core from the reflector and reducing its reactivity. The pressurizer consists of a chamber, connected with the core, which is heated by steam in a jacket to generate 1000 psia vapour pressure above the solution level. The gas outlet, fuel-solution outlet, and pressurizer stem are concentric pipes extending from the top of the core through the pressure-vessel head. Motors and mechanisms for moving the control elements operate in an atmosphere of helium, which also is the reflector-pressurizing medium.

Two essentially separate fluid systems comprise the entire reactor system, shown schematically in Fig. 1. These are the fuel system and the reflector system. Each system is divided into high-pressure and low-pressure parts separated by valves and feed pumps. The high-pressure portion of each system consists of a circulating pump, a heat exchanger, and the reactor vessel, connected by high-pressure piping. Heat is generated by the fission process in the fuel solution flowing through the core vessel and is removed in the heat exchanger and in the D_2O cooler. The fuel-system heat exchanger is a steam generator and the D_2O cooler is a feedwater heater.

Core Vessel :—The core tank is made of two hemispheres, press-formed of stainless-steel plate, $\frac{3}{4}$ in. in thickness, machined inside and outside to a finished inside diameter of 18 in. and a thickness of $\frac{3}{16}$ in. and welded together. The stem welded to the top is a 3-in. pipe containing two concentric tubes. The smaller is for removal of gas from the vortex, while the other forms the flow annulus through which fuel leaves the core.

Under steady-state conditions the size of the gas vortex in the core is controlled by a valve in the gas let-down line in response to a liquid-level controller on the pressurizer. Enlargement of the vortex forces liquid into the pressurizer, causing the level controller to open the valve and reduce the vortex diameter. A continuous liquid feed tends also to raise the level, so that some liquid must be removed with the gas. Thus, the vortex is always held at a diameter small enough for some liquid to be drawn into the gas-removal hole at the top.

Pressure Vessel :—The pressure vessel is a single forging of steel, with a minimum thickness of 3 in. The flat head is 10 in. thick, also forged of steel. Stainless-steel pipes are sealed to the head by welding.

Pressurizer :—The pressure in the fuel system is maintained by a steam-heated pressurizer. The jacket around the lower section is supplied with steam from a small electrically heated boiler whose electric power input is controlled by a pressure-sensing element connected to the top of the pressurizer. The level of solution in the unit is controlled by a specially designed level-control device.

The pressurizer is an all-welded assembly of stainless-steel pipe and fittings designed for an internal pressure of 2000 psi at 600° F.

Steam Generator :—The main heat exchanger is a tube-and-shell type with the tubes bent into a U-shape. Fuel solution circulates through the tubes to generate steam in the shell. A double tube sheet is used, with tubes expanded in one and welded to the other. A connection into the space between them provides indication if a leak develops in any of the tube joints, before it can contaminate the steam. All surfaces in contact with fuel solution are of stainless steel, but the shell and back tube are of carbon steel.

The flow of fuel solution and its average temperature are constant.

Circulating Pump :—The pump used for circulating the fuel solution is a canned-motor type capable of delivering 100 USgpm at a head of approximately 100 psi. Leakage is eliminated by elimination of the shaft seal. The increased air gap between stator and rotor in the motor, however, results in an efficiency of only 34%.

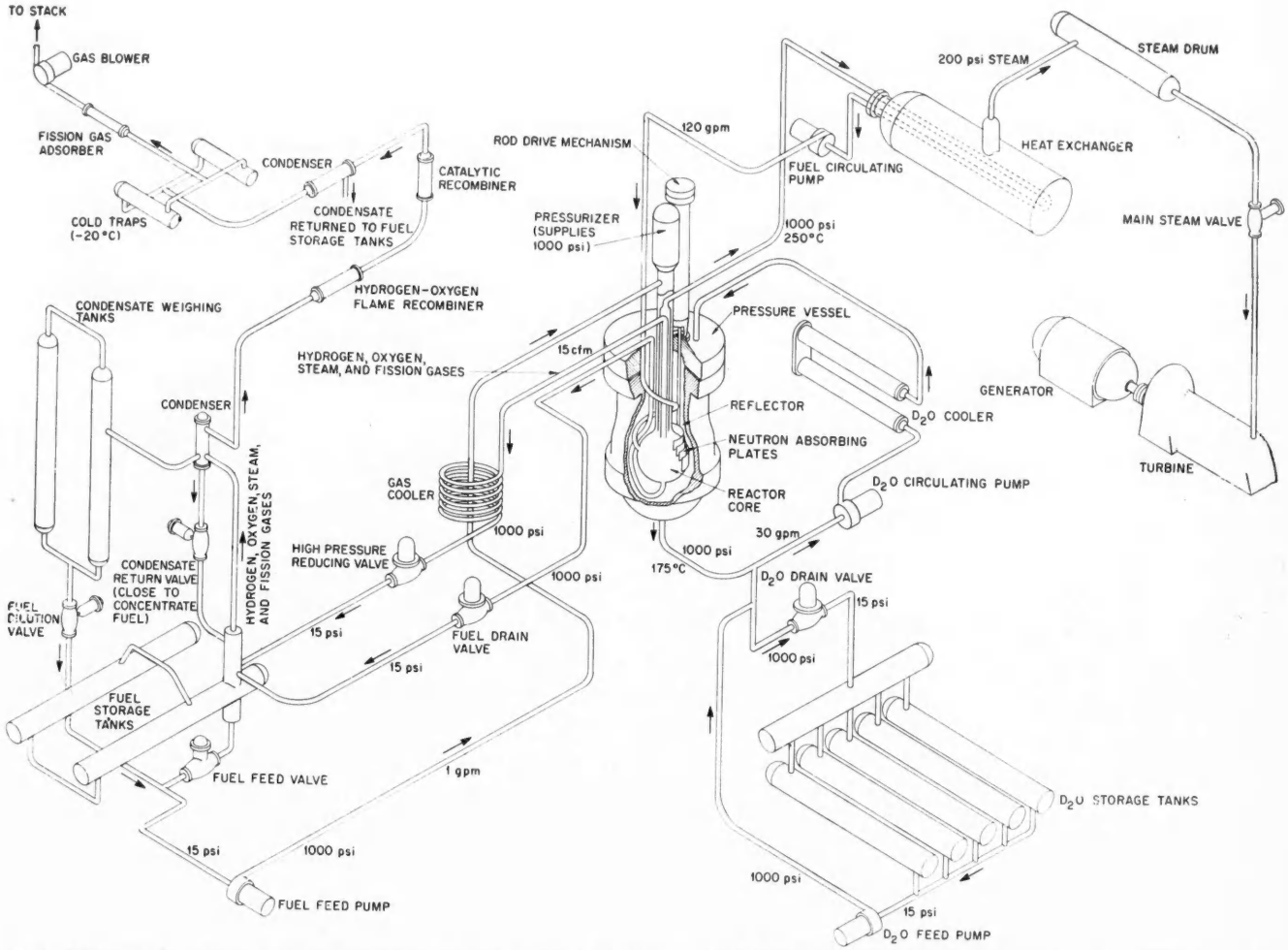

Fig. 1. Schematic flow diagram, showing equipment and conditions of the fuel system and the reflector system throughout the entire reactor operating cycle.

Gas-Removal System :—Gas, vapour, and liquid from the vortex in the core vessel are removed through a throttling valve which discharges into the low-pressure system. The throttling valve is controlled by liquid level in the pressurizer. Part of the pressure drop, approximately 180 psi, occurs in the annulus of a concentric-tube heat exchanger, in which the temperature is reduced to 183° F before reaching the valve.

Recombiners :—The mixture in the let-down stream is separated in the dump tanks, and the gases are recombined either in the flame recombiner or in the catalytic recombiner. The flame recombiner consists of a combustion chamber, a nozzle, and a spark plug. The gas is ignited as it emerges from the nozzle and forms a flame down the centre of the chamber. The chamber walls are cooled by a water jacket. Products of combustion are desuperheated and condensed, condensate being returned to dump tanks and pumped into the reactor by the feed pump.

The catalytic recombiner is a packed bed of platinum-coated alumina pellets. In passing over the platinized surfaces the hydrogen and oxygen recombine, emitting the heat of combustion. Unless the entering gas is diluted below the combustible concentration, an explosion will result. Consequently, steam is mixed with the gas to make it non-explosive.

Non-condensable gases, consisting mostly of krypton and xenon fission products, are absorbed in a charcoal bed, where they decay to lower levels of activity before being pumped out of the stack.

Feed Pump :—Solution is pumped up from the low-pressure system to the high-pressure system by means of a hydraulically actuated diaphragm pump.

Valves :—All valves in contact with either fuel solution or reflector fluid are of the bellows-sealed type and are operated by specially designed bellows air operators. The bellows seal is backed up by a packing and the intermediate space is connected to a leak-detection system.

Piping and Flanges :—The piping system is all-welded, except in places where removal of component equipment is anticipated. In such cases as the circulating pump, where failure of the thin can is considered to be probable, flanged pipe joints are provided. All flanges used at 1000 psi operating pressure are of solid stainless steel.

Radiation Shielding :—The radiation shield is constructed of solid blocks of a special concrete, partly laid in mortar and partly stacked dry. The concrete is a mix of Portland cement and barytes aggregate with a resulting density of 225 lb/cu ft. Space inside the shield is compartmented, to reduce to a minimum the radiation level in any one compartment and thus facilitate maintenance. Since the reactor vessel is the most intense source, it is in a centre compartment surrounded by a minimum of 7 ft of concrete, at least 2 ft of which separate it from the nearest auxiliary compartment. The inner 2 ft of concrete contains 1% boron in the form of colemanite ore to increase its absorption for neutrons with minimum resultant induced activity. Each compartment may be opened at the top by lifting barytes concrete covers. The entire shield structure measures 22 ft wide, 26 ft long, and 18 ft high.

Emergency Cooling :—As a matter of safety, a cooling system is provided which will dissipate all heat due to decay of fission products after shut-down, without dependence upon any outside source of water or electric power. This is accomplished by a natural-convection water system connecting dump-tank cooling jackets with air-cooled finned tubes outside the shield. This system is capable of removing 95,000 BTU per hr for a short time and 45,000 BTU per hr continuously.

Steam System :—The steam system in this plant has the characteristic that its steam pressure increases as the load decreases. When load on the turbines is suddenly reduced, pressure rapidly builds up in the steam generator, reducing the temperature difference to just that required to transmit the demand load. Reactor-fuel temperature is held constant by the negative effect of temperature on reactivity. Rise of temperature in the core causes the solution to expand, expelling solution, and consequently uranium, from the core and reducing its tendency to react. Operation has proved this to be a stable characteristic.

In the steam generator, only 0·049 in. of stainless steel separates the core solution from the boiler water. Although delayed neutrons are emitted in this part of the loop, induced activity in the steam is low enough to permit operation with no shielding around steam lines or turbine. However, if one of the tubes fails or develops a leak, the steam will contain very radioactive gases and vapours from fuel solution, endangering operating personnel. As a precaution against this event, the steam passes into an accumulator inside the shield, which provides a minimum of 14-sec time delay in the steam flow at design power level. A radiation monitor on the steam pipe entering the accumulator is shielded against reactor radiations and is sensitive to activity in the steam. The monitor provides a signal for the automatic closing of a valve in the exit line from the accumulator. The same signal causes a valve to be closed in the feedwater line, thus isolating all activity inside the shield.

Outside the shield the steam system is made up of conventional equipment for this type of system. Electric output of the generator is synchronized into the laboratory power system.

Instrumentation :—All important indicating, recording, and control instruments are located on panels in the central control room. Designs of the panels and control console are such that a single operator seated at the console can reach handles controlling all important operations of the reactor, turbine, and generator. From the same position he can read all pressures, temperatures, flow rates, and nuclear levels on the large panels. A panel on the main board indicates which valves are open and which are shut, and an adjacent bank of air valves enables him to open or close remotely any valve inside the shield not controlled at the console itself.

Temperatures are measured by thermocouples connected to instruments in the control room. Pressure and liquid level are transmitted electrically from detectors inside the shield to the control-room instruments.

Operating History

The reactor was in operation intermittently over a period of two years. During that time the following totals were accumulated :—

Total hours with liquid circulating	4498
Total hours with reactor critical	1950
Total hours at reactor power over 100 kW ...	720
Maximum reactor power level attained	1600

Kinetic experiments have been performed, in which uranium has been suddenly introduced at a rate of 75 grams per sec. Doubling times as short as 30 milliseconds were attained. The power arose from 30 W to 11×10^6 W in 1 sec, and returned to normal in another 0·1 sec. In this experiment the worst combination of circumstances was imposed on the reactor. It was demonstrated successfully that the equipment was sufficiently stable, in the nuclear sense, to withstand transients greater than those to be expected from operating errors.

Leakage experience with the reactor has been satisfactory. Although several leaks were experienced in the start-up phases, no leakage was found during the final 12-month period. Leaks are detected quickly by radiation detectors constantly monitoring the ventilating air, so that the reactor can be shut down and drained before a large amount of solution is lost.

The Causes and Suppression of Transformer Hum

By E. GRUNDER. (From *Bulletin Oerlikon*, Vol. 34, No. 303, 1954, pp. 23-30, 20 illustrations.)

By proper planning and by adopting means to prevent the radiation of transformer hum, subsequent complaints and additional costs for later structural alterations can be avoided. This article facilitates the investigation of such problems and illustrates the effectiveness of available means of reducing transformer hum.

ALL transformers hum when energized and, although this hum can be reduced by a proper choice of maximum induction and by suitable design and careful assembly, economic considerations usually impose a compromise solution to the problem. In this connection, therefore, this article discusses questions of practical importance regarding transformer hum, particularly insofar as the possibilities of reducing this noise by suitable transformer installation are concerned.

CAUSES OF TRANSFORMER HUM

The most important cause of hum is the magnetostrictive effect of the transformer laminations, i.e., the elongation of the core and the yokes when magnetized. Contributory causes are the vibrations set up by the forces acting in the joints between core and yoke; these are, however, not considered in this article, since by careful erection and design they can be reduced sufficiently so as to become insignificant, compared with the former cause.

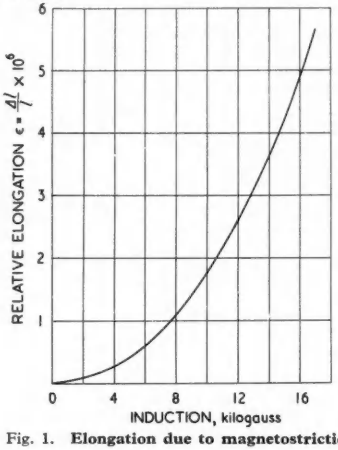

Fig. 1. **Elongation due to magnetostriction.**

The magnitude of the relative increase in length $\varepsilon = \Delta l/l$ due to magnetostriction is approximately 10^{-6} for ordinary transformer laminations and average flux densities, and increases with the square of induction B. This increase in length takes place in the direction of the magnetic flux (Fig. 1). With a mains frequency of 50 cps the fundamental of the vibration frequency is 100 cps. This is thus the fundamental note of the hum. Owing to the non-linear relationship between induction B and magnetostriction ε, a number of harmonics is produced, with frequencies mainly of 200 and 300 cps.

These vibrations of the iron core are transmitted to the tank and the chassis, either directly or through the oil. From there they are radiated as airborne sounds or as mechanical vibrations.

SOUND-LEVEL MEASUREMENT

When dealing with a sound containing a mixture of frequencies, chief interest lies in the sound level perceived by the human ear and expressed in phons. The frequency sensitivity of the ear varies and depends on the phon value. An instrument called a sound-level meter is usually employed for noise-level measurements, and uses a microphone, amplifier, and an indicating instrument, which reads directly in decibels. The amplifier is frequency-sensitive and contains three filter circuits, each of which provides a different response characteristic. These three characteristics make it possible to relate the instrument indication with the response curves of the human ear, *viz.* :—

Characteristic *A* : Approximation to the 40-phon graph
„ *B* : „ „ „ 70-phon „
„ *C* : „ „ „ 100-phon „

Characteristic *C* is horizontal and corresponds to the physical sound level. For transformer-noise measurement curves *A* and *C* are employed exclusively (Fig. 2).

The sound level of a transformer is always measured with characteristic *A* at a distance of 30 cm from the tank and with sound radiation unrestricted as far as possible. It is expressed in phons (approximate) or better still in *A* decibels (db_A). The reason for this procedure is based on the following consideration :— When a transformer is troublesome, its noise level is of the order of 40 phons or less; response curve *A* is therefore the most appropriate, even though higher db_A values may be recorded during the works test, where readings are taken at a distance of only 30 cm. A distance of 30 cm was chosen so that measurements become independent of the background-noise level and the sound-radiation conditions. This test procedure produces results which are specific and reproducible.

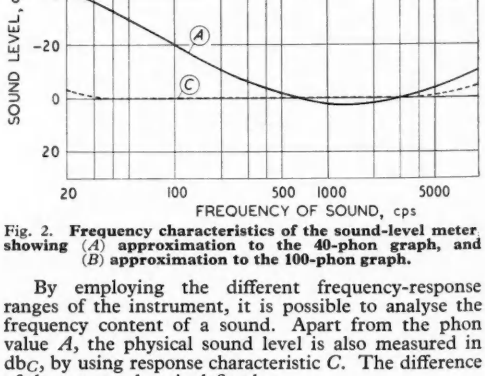

Fig. 2. **Frequency characteristics of the sound-level meter showing (*A*) approximation to the 40-phon graph, and (*B*) approximation to the 100-phon graph.**

By employing the different frequency-response ranges of the instrument, it is possible to analyse the frequency content of a sound. Apart from the phon value *A*, the physical sound level is also measured in db_C, by using response characteristic *C*. The difference of these two values is defined as

$$\text{Harmonic index } H = (C - A) \quad [\text{db}]$$

Fig. 2 shows that, for a pure note with a frequency of 1000 cps, $H = 0$ db; for a note of 100 cps this index is 20 db. If the noise produced by a transformer has a high *H*-index, it contains few harmonics; if this index is low (approximately 10 db or less), it contains a large number of harmonics.

It is not permissible to add decibel values algebraically; they can only be summated after conversion into sound intensity.

Sound level has been defined as

$$L = 10 \log \frac{I}{I_0} \quad [\text{db}]$$

If two different sound levels L_1 and L_2 have to be added, then the sum of their intensities $(I_1 + I_2)$ must be

substituted in the above equation, so that

$$\Sigma (L_1, L_2) = 10 \log \frac{(I_1 + I_2)}{I_0} =$$

$$= 10 \log (10^{L_1 10} + 10^{L_2 10}) \quad \text{[db]}$$

Influence of Operating Conditions

Changes of voltage influence the noise. As shown in Fig. 3, the induction which is proportional to the applied voltage is directly responsible for the noise producing vibrations. The relationship between voltage E and sound level L is not linear, but a considerable number of measurements shows that, for a range of $\pm$ 10% of the nominal voltage and irrespective of the size of the transformer, the following rule is a good approximation :—Change of sound level ΔL due to a 10% voltage change equals 3 db$_A$.

Thus, for example, a voltage rise of 10% causes an increase in sound level of 3 db$_A$, which is equivalent to the switching-in of a second identical transformer at the nominal voltage.

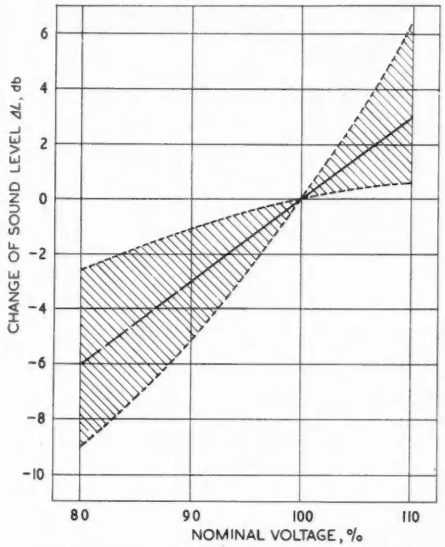

Fig. 3. **Influence of voltage on noise emission.** The shaded area contains the results of noise tests taken on 25 transformers with ratings between 600 and 50,000 kVA.

This relationship between sound level and voltage or induction is, however, not sufficiently significant to warrant the use of lower inductions to reduce hum. In order to produce an easily noticeable improvement of, for instance, 10 db$_A$, it would be necessary to reduce the induction by approximately 50%. This means that, for the same transformer output, the core section would have to be doubled.

Load variation has practically no influence on the sound level of the noise since, between no load and full load, the induction remains practically unchanged. Hum measurements are usually conducted with unloaded transformers.

Transformer Rating and Noise Emission

For ease of investigation it is best to consider three ranges, i.e., (1) units up to 300 kVA ; (2) units with a rating of 300 to 1000 kVA ; and (3) units with a rating of more than 1000 kVA.

Individual transformers in range (1) produce a hum with a sound level of less than 55 db$_A$. Unless a considerable number of these units is installed in the same station, the usual enclosure of the substation provides sufficient sound insulation to prevent disturbance in the neighbourhood.

Transformers with ratings between 300 and 1000 kVA are the most likely sources of trouble. They are used as distribution transformers in large numbers in built-up areas and the level of the emitted sound can exceed 60 db$_A$. When installing transformers in this range it is therefore important to pay particular attention to the hum problem.

Transformers with ratings in excess of 1000 kVA are installed exclusively in large substations, in factories, or out-of-doors, i.e., in locations where either the background noise level is already rather high or where there are no dwellings in the vicinity.

The sound intensity I of a transformer installed out-of-doors is reduced in inverse proportion to the square of the distance d from the transformer, provided that unrestricted radiation is assured.

As a rough guide, it can be assumed that, for distances very much larger than 10 m, the sound level decreases by 6 db if the distance is doubled. This is illustrated in Fig. 4. The sound level at a distance of 10 m will depend on the radiating conditions, i.e., on the tank dimensions, and will lie roughly between the two curves.

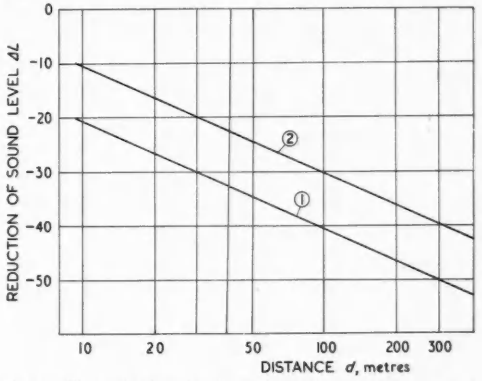

Fig. 4. **Theoretical reduction of sound out-of-doors as a function of distance, with (1) a transformer of about 1000 kVA and (2) a transformer of about 50,000 kVA.**

Installation Problems of Transformers

The design of transformers with a rating between 300 and 1000 kVA is generally so satisfactory that hum is reduced to a minimum. These transformers are mostly installed in specially erected buildings and it is therefore necessary to ensure sufficient sound insulation of the latter.

For sound waves a wall represents a plate subject to flexural oscillations ; the face opposite that on which the sound waves impinge will therefore also radiate sound. Nevertheless, a wall does reduce the noise level because part of the incident sound wave is reflected and part of its energy is absorbed by the vibration.

Sound Reduction due to Walls :—

Sound reflection is defined by a reflection coefficient r, which is the ratio of reflected to incident sound intensity, so that

$$r = (I_1 - I_2)/I_1,$$

where I_1 and I_2 are respectively the intensity of a sound striking a wall and after passing through it.

It is more usual, however, to refer to a sound reduction coefficient D, which is the ratio (in db) of total sound energy P_1 impinging on the wall to sound energy P_2 passing through it. The energy (in watts) of a sound intensity I_1 hitting a wall of area S is expressed by the following equation :—

$$P_1 = I_1 S$$

Similarly, for the energy of the sound passing through the wall,

$$P_2 = I_2 S$$

Introducing the reflection coefficient r, this can be written as

$$P_2 = I_1 (1 - r) S \quad \text{[watts]}$$

The sound-reduction coefficient of a wall can therefore be expressed by

$$D_W = 10 \log \frac{P_1}{P_2} = 10 \log \frac{I_1}{I_2} = 10 \log \frac{1}{1 - r} \text{[db]} \quad (1)$$

This coefficient can be determined experimentally by measuring the sound intensities I_1 and I_2 on both sides of the wall. It is comparatively low for a frequency of 100 cps, which is the main component of transformer hum. Empirical investigations show that this coefficient at 100 cps is approximately

$$D_W \approx 13 \log G \quad \text{[db]} \quad \ldots \quad (2)$$

where G is the weight of wall per unit area, expressed in kg/m^2.

Generally, walls contain openings in the form of windows and doors. These are of lighter construction than the masonry and possess a reduction coefficient D_2. As an approximation, the overall coefficient of a wall containing openings is a function only of coefficient D_2 and the ratio of wall area S to area of opening S_2 :—

$$D_W \approx \left(D_2 + 10 \log \frac{S}{S_2} \right) \quad \text{[db]} \quad \ldots \quad (3)$$

The most suitable form of building for a transformer substation is therefore one with massive walls standing in an isolated position. In order to provide good sound reduction, all openings in the walls should be reduced to a minimum. Doors must fit tightly and should be of heavy construction ; good natural illumination can be effectively provided by small cast-glass panes in reinforced-concrete frames. Ventilation openings should be kept as small as possible and perhaps should be fitted with acoustic baffles. Sound radiation in the open countryside is also affected by trees and shrubs.

Enclosing a sound-producing source does not only insulate this from the surrounding space, but it also increases the density of the sound energy inside. This is equivalent to an increase of the inside sound level. This increase will depend upon the enclosed volume and the sound absorption of the walls.

Sound Absorption :—

Sound absorption is defined by the ratio a of the absorbed sound intensity I_3 to the incident sound intensity, so that

$$a = I_3 / I_1^*,$$

where I_1^* is the increased inside sound intensity corresponding to an increased energy density due to the enclosure of the sound source. Also,

$$P_1 = P_3 + P_2 \quad \text{[watts]}$$

and $P_3 = I_1^* S a$ [watts],

where P_3 is the absorbed sound energy.

Considering also reflection due to the wall, the part of the sound energy passing through the wall can then be expressed by

$$P_2 = I_1^* S (1 - a) (1 - r) \quad \text{[watts]}$$

The original sound intensity is therefore reduced by absorption and reflection by the following amount :—

$$\Delta L = 10 \log \frac{P_1}{P_2} = 10 \log \frac{1}{1 - r} + 10 \log \left(1 - r + \frac{a}{1 - a} \right)$$

$$\Delta L = D_W + 10 \log \left(1 - r + \frac{a}{1 - a} \right) \quad \text{[db]} \quad \ldots \quad (4)$$

In most practical cases the reduction coefficient $D_W > 10$ db and the absorption coefficient $a < 0{\cdot}3$. Under these conditions eq. (4) can be simplified and approximated thus :—

$$\Delta L \approx D_W + 10 \log a \quad \text{[db]} \quad \ldots \quad (5)$$

This simplified equation requires only a knowledge of the reduction coefficient D_W of the wall, calculated in accordance with eq. (2) and the absorption coefficient a.

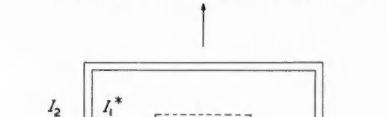

Fig. 5. Factors involved in the case of a transformer within an enclosure.

In the specific case of a transformer within an enclosure (Fig. 5), the ratio of the surface of the enclosure to the radiating surface of the transformer must also be considered. The sound energy radiated by the transformer is

$$P_1 = I_1 S_T \quad \text{[watts]}$$

Also, $P_1 = I_1^* S a + P_2$ [watts]

The sound level reduction can therefore be expressed as

$$\Delta L \approx D_W + 10 \log \left(1 - r + \frac{a}{1 - a} \right) + 10 \log \frac{S}{S_T}$$

where

S = total surface of the transformer enclosure ;

S_T = measuring surface of the transformer defined by the tank dimensions plus the standardized measuring distance of 30 cm, i.e., the enveloping surface in m^2 on which sound intensity I_1 was measured under conditions of unrestricted radiation ; and

a = average absorption coefficient of the walls.

Applying the simplifications according to eq. (5), the sound level as measured in the makers' works is reduced by

$$\Delta L = D_W + 10 \log a + 10 \log \frac{S}{S_T} \quad \ldots \quad \ldots \quad (6)$$

This presupposes a symmetrical energy distribution.

Eq. (6) shows that the sound-absorption capacity of a wall can be increased by suitable surface treatment and also that the transformer enclosure should be kept

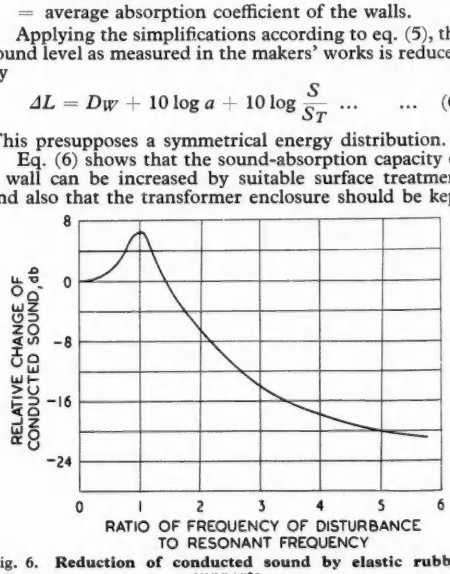

Fig. 6. Reduction of conducted sound by elastic rubber supports.

as spacious as possible. Obvious practical considerations, however, make it impossible to comply with the latter condition, but eq. (5) is also applicable in this instance for a rough approximation.

In the case of unrestricted radiation, total absorption of sound takes place, and absorption coefficient $a = 1$. In any other case a is smaller than 1. Unfortunately, however, this coefficient has the lowest values for the lower frequencies. Thus, for instance, for a plastered brick wall, a is in the region of 0·1 for 100 cps; in order to increase it to 0·3, thick layers of special sound-absorbing material would have to be applied.

As an example, in accordance with eq. (2), the reduction coefficient D_W of a wall with $G = 300$ kg/m² is 32 db. The absorption coefficient a is assumed as 0·1; the sound-level reduction, in accordance with eq. (5), $\Delta L = 32 - 10 = 22$ db. By applying an absorbing layer of fibrous material of 4 cm in thickness at a distance of 2 cm from the wall, it is possible to increase a to 0·25 for 100 cps. This makes $\Delta L = 32 - 6 = 26$ db. The gain, therefore, is only 4 db.

The application of sound-absorbing material produces a noticeable improvement only in a space with very poor absorption (large amount of echo). It is important not to forget to cover the floor and ceiling as well.

Conducted Sound :—

There are cases where it is not possible to avoid erection of a substation in the immediate vicinity of dwelling houses or where it even may have to form part of the building. The transformer vibrations can be transmitted through the foundations and other solid structures directly to the dwellings, where they are transformed into radiated sound. Under certain conditions it is even possible to transmit a larger volume of noise by conduction than by radiation.

Insulation against Conducted Sound :—

The most effective means of reducing the transmission of conducted sound is to support the transformer on elastic rubber mountings. This arrangement has a resonant frequency

$$f_0 = 5 \sqrt{\frac{1}{x}} \text{ [cps]} \quad \ldots \quad \ldots \quad (7)$$

where x is the elastic deformation [cm] of the rubber mounting due to the weight of the transformer.

This resonant frequency f_0 should be lower than the frequency f_s of the disturbance; the frequency ratio $\lambda = \frac{f_s}{f_0}$ should be at least greater than 2 (Fig. 6).

U. S. A.

Aeration in Lubrication and Hydraulic Systems

By B. R. WALSH. (From *Product Engineering*, Vol. 26, No. 5, May 1955, pp. 136-139, 9 illustrations.)

AERATION of oil is of importance in fluid-system design, since the presence of air contributes to loss of pump efficiency, defective lubrication of bearings (cavitation erosion), loss of oil by foam overflow, reduced pressure in hydraulic and pressure lubrication systems, and erroneous readings of sump-oil level.

Full liquid delivery from a positive displacement pump cannot be expected if entrained air is present. The pump will deliver a volume of liquid reduced by the volume occupied by air. Also, collapse of air bubbles when subjected to pump discharge pressure causes objectionable noise and may erode pump parts.

The oil delivery characteristics of a typical spur-gear pump are shown in Fig. 1 with various percentages of entrained air at pump-inlet conditions plotted against pump-inlet pressure. The reduction in liquid delivery is greater than the volume of air at the pump inlet since the air increases in volume as it enters the pumping members, the magnitude of increase depending upon the pressure reduction inside the pump.

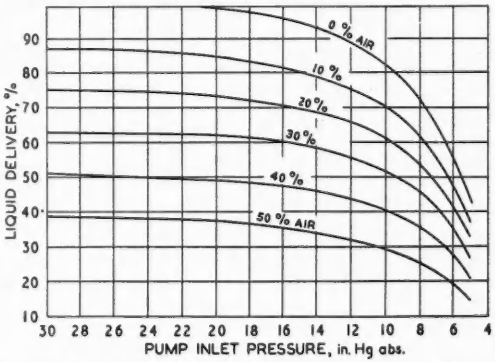

Fig. 1. **Effect of entrained air on the oil-delivery characteristics of a typical spur-gear pump.**

Pressure reduction within the pump differs with each design. In a spur-gear type, this reduction is a result of jet and friction losses of oil entering the tooth spaces, turbulent flow losses in the intake chamber, skin friction, and the centrifugal force of liquid in the tooth spaces. The clearance volume of the pumping members further reduces the pump capacity in the presence of entrained air. In a spur-gear pump, this volume is the volume trapped between two pairs of teeth at the instant of sealing from both suction and discharge. In this connection, it should be understood that, because the air compresses when subjected to pump discharge pressure, the percentage of oil in the clearance volume is greater when returned to the pump inlet than it was under suction conditions.

Sources of air entrained in pump oil include excess capacity of the scavenge pump in dry-sump systems, splashing of oil in the supply tank by the return system, dissolved air in the oil, and air leaks in the pump inlet line.

In dry-sump systems using a scavenge pump, the capacity of this pump is usually larger than that of the main supply pump. As a result, the scavenge pump sucks air, which becomes distributed throughout the oil. The discharge pressure of a positive-displacement scavenge pump determines the size and separation characteristics of air bubbles in oil; this pressure, in turn, depends upon the size and resistance of tubing and apparatus, such as coolers and filters, installed in the discharge line. Fig. 2 shows how air in tank-outlet oil can vary with scavenge-pump discharge pressure and indicates that scavenge-pump discharge pressure should be as low as practicable. Fig. 3 shows that air entrainment in outlet oil increases as tank temperature increases. In this instance, the flow is laminar, and bubble rise is an inverse function of viscosity (indicated in Fig. 3 in Saybolt universal seconds (SUS)). In the event of some turbulence in the tank, a change of viscosity with increased temperature has less effect on air separation, since bubble rise is independent of viscosity in turbulent flow.

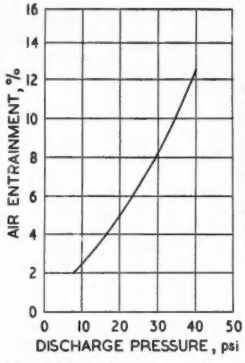

Fig. 2 (left). **Variation of air entrainment in tank-outlet oil with discharge pressure for an aircraft-engine scavenge pump.**

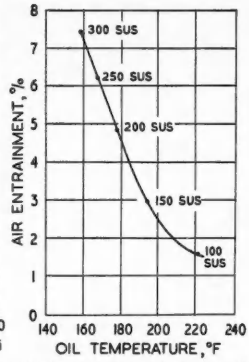

Fig. 3 (right). **Variation of air entrainment in tank-outlet oil with temperature.**

Installing oil coolers between the tank and supply pump, instead of between the scavenge pump and tank, will reduce air entrainment by increasing the temperature of oil in the tank and also will reduce scavenge-pump pressure. This arrangement will result in tank-oil temperatures approximately equal to engine-oil temperatures.

One method of reducing free air handled by a scavenge system uses two separate pumps. One pump has a capacity only slightly in excess of normal engine flow, and the other provides the additional excess capacity for scavenging and has its inlet slightly above the normal sump level. The latter pump, normally handling air, has its discharge connected to that of the main pump through a check valve. An air bleed, ahead of the check valve, is connected with the sump, so that, if the oil level rises in the sump, the auxiliary scavenge pump primes itself and builds up enough pressure to open the check valve and deliver oil to the tank. The oil-flow rate to the sump through the bleed hole is negligible.

Other methods for reducing free air handled by scavenge pumps involve means for maintaining sump-oil level above the pump inlet. This can be accomplished either by controlling pump speed or by-passing scavenge oil back to the sump. One scheme for by-passing oil uses a float-controlled by-pass valve, while others depend upon hydraulic control.

In any event where liquid is recirculated, air entrainment may be decreased if the stream entering the supply tank is introduced in such a way as to avoid splashing and turbulence. This can often be accomplished simply by designing smooth, submerged return systems. In some cases it may be desirable to install baffles between the incoming and outgoing liquid, to assist air bubbles in rising to the surface. The time the liquid remains in the supply tank is important to permit the escape of entrained air. For example, tests on several cylindrical aircraft-type tanks, with oil at a viscosity of 180 SUS and 185° F (Fig. 4), show that residence time should not be less than two minutes for satisfactory air separation. For more viscous liquids, the time should be increased. Also, the distance air bubbles travel to reach a free surface should be kept to a minimum.

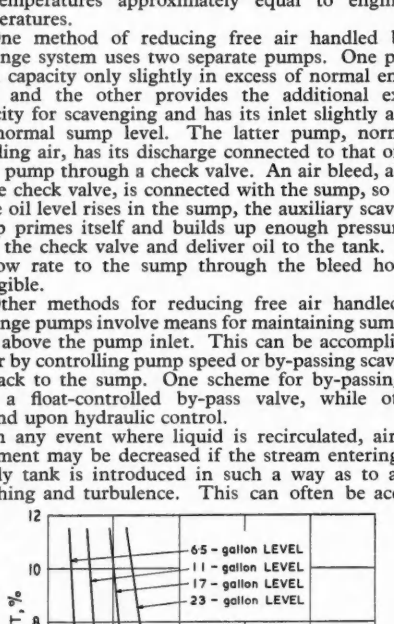

Fig. 4. **Variation of air entrainment with residence time for a typical aircraft-engine oil system.**

Liquids in contact with air contain air in solution. The weight of air will dissolve in proportion to absolute pressure, the dissolved volume measured at any saturation pressure being constant. For example, under equilibrium conditions, a lubricating oil will have in solution about 0·09 cu ft of air per cu ft of oil. Since this air will come out of solution when pressure is reduced, as occurs in a pump inlet system, it will appear in the form of entrained bubbles which will reduce the pump capacity.

Where high suction is encountered, sources of air leaks, such as loose pipe connections, filter caps, pump-shaft packing, and external pressure-regulating valves, should be avoided.

Deaerators

Deaerating devices are sometimes used to remove entrained air. Numerous types have been tested, some of which rely upon the velocity of entering oil to provide sufficient centrifugal force for air separation. Usually, at least 3 *g* are necessary for satisfactory performance.

Indications are that the efficiency of deaerators in air separation depends largely upon the type of air-oil mixture being circulated. For example, where the incoming mixture had been subjected to high pump pressure, only 5% separation was obtained, whereas when the incoming mixture was subjected to low pressure most of the entrained air was in the form of large bubbles, and 90 to 95% separation was obtained.

As a rule, air-oil mixtures are subjected to high pump pressure, and static-type deaerators generally are inadequate. For such applications power-driven deaerators are required. Tests on five power-driven units showed deaerating efficiencies varying from 70 to 75%.

It cannot be assumed that a deaerator which is efficient in one flow system will be good in another. Tests indicate that an optimum size of unit exists for any application, depending upon flow rate, oil viscosity, and dispersion (bubble size and pressure). Because of the decrease in efficiency with oil pressure, deaerators should be installed in a low-pressure section of the system.

Hydraulic Systems

Pump difficulties can be encountered in hydraulic systems operating at high pressures, such as 1200 psig, and having a surge chamber with air in direct contact with the oil surface.

For example, if oil is exhausted to atmospheric pressure after passing through work cylinders or hydraulic motors, all the dissolved air can come out of solution except 0·09 cu ft, corresponding to saturation at atmospheric pressure. This volume of released air measured at atmospheric pressure can amount to approximately 7·3 cu ft per cu ft of oil.

This condition can and does give trouble in hydraulic systems. For example, the compressibility of air may set up surging conditions in the system.

Aeration in Engine Bearings

Lubricant supply for connecting-rod and wrist-pin bearings in a diesel or high-speed reciprocating engine can be affected by accelerating and decelerating forces

acting on the column of oil within a drilled connecting rod. When an engine is operated at high speed, deceleration of the rod can be of such magnitude on the upper half of the upstroke that oil will be forced through the wrist-pin bearing at a rate in excess of supply to the crank-pin bearing. Under this condition, air will be sucked into the crank-pin bearing to make up the volume deficit, thereby interrupting the lubricating-oil film.

On the return stroke the reverse is true; in other words, forces on the lubricant remaining in the rod hole can retard flow into the crank-pin bearing. Besides resulting in premature lubrication failure, such cyclic oil flow can be a factor in promoting cavitation erosion. During such erosion, sections of bearing material are removed by a hammering action which is a result of the rapid collapse of air bubbles in the lubricant. If the lubricant supplied to the rod is used for piston cooling, which is generally the case in diesel engines, inadequate piston cooling may also result. To overcome these difficulties, it may be necessary to supply the engine with an oil pump of greater capacity or to reduce pump requirements. For example, a separate pump and piping system could be used for piston cooling of diesel engines.

In splash systems, while the oil level must be high enough to permit suitable splashing of oil for lubrication of cylinder walls and bearings, it must not be so high that aeration can cause erroneous readings of sump-oil level, which should preferably be taken when the machine is idle.

Since aeration seems to be largely a question of the construction and operation of a lubricating-oil system, every reasonable design precaution should be taken to avoid any chance for entrance of air to occur.

Anti-Foam Agents

The elimination of foam is desirable, to reduce aeration in some fluid systems and oil loss by foam overflow. In those instances where foaming occurs, even with good mechanical design a good foam-suppressing agent can be used for eliminating or reducing it. Such agents are selected to control foam without interfering with the functional properties of the lubricant.

It should not be assumed that the use of an anti-foam agent will necessarily solve all aeration difficulties. It has been noted that, while the total volume of air entrained in an oil containing an anti-foam agent was reduced, a pump with its inlets submerged near one end of a supply tank actually withdrew a larger volume of air. This can occur because, while anti-foam agents promote coalescence of air bubbles of moderate size to form larger bubbles which escape more rapidly to a free surface, the rate of release of very small air bubbles is sometimes retarded.

SWITZERLAND

The Atomization of Liquids

By H. A. Troesch. (From Thesis No. 2266, *Eidgenössischen Technischen Hochschule, Zurich*, 1954, 14 pp., 6 illustrations.)

The development of atomizers has been based almost entirely on empirical principles. As a result, knowledge in this field has not substantially increased during the past twenty-five years. There is still no basic theory in agreement with experiment for the breaking up of liquids. It is significant of the difficulty of this problem that, even up to now, the system of differential equations describing the atomization phenomenon has not been published in its complete form.

These facts are particularly remarkable because atomizing devices are used for a wide range of applications. There is an extensive literature on the subject, dating back to the period around 1880, and since then many attempts have been made to clarify the physical conditions governing atomization processes, though the results and opinions derived from these are contradictory. In the case, for instance, of the influence of compression pressure on the size of droplets in diesel-engine cylinders, the relations derived are not even qualitatively in agreement with experimental values. Thus, the theoretical solution of the problem remains to be found, together with an explanation of the breaking-up process and the reason for the formation of a mixture of droplets of unequal sizes.

The atomization process takes place in such a short time that it cannot be followed visually in its individual phases. Moreover, high-speed cinematography has not as yet proved as valuable an aid as would have been expected. Consequently, for theoretical considerations, it is necessary to use certain assumptions, *viz.* :—

(1) In the mixture of droplets occurring in an atomization process, the size of the largest droplet will be determined by stability requirements.
(2) All other droplets will be generated in accordance with statistical laws.

In this report, the above assumptions are used in conjunction with the knowledge available on the breaking up of liquid jets. The size of the largest possible droplet will be determined by a stability criterion based on dimensional considerations. The statistical distributions for other droplets will be correlated with certain physical parameters, which allow a physical interpretation of the events. It will thus be possible to predict the droplet characteristics for certain classes of atomizers and to obtain qualitative indications for others. The limits of validity of the new relations will also be considered.

Types of Atomizers

Atomizers can be classified into two main groups, i.e., centrifuging atomizers and velocity atomizers. Velocity atomizers can be subdivided into three main types, i.e., pressure atomizers, with liquid in motion in still air or in some other secondary medium; swirl-nozzle atomizers; and compressed-air atomizers, with liquid almost at rest.

Pressure atomizers can themselves be of two types, i.e., those with rotating nozzles and those with stationary nozzles. Swirl-nozzle atomizers can also be of two types, i.e., those with uncontrolled air cores, and those with controlled air cores. Finally, compressed-air atomizers can be subdivided into two types, i.e., general atomization in which the liquid is injected at any angle relative to the direction of velocity of the atomizing air, and special or classical atomization in which the liquid is injected in a plane perpendicular to the direction of air velocity.

The group designated as centrifuging atomizers has been investigated theoretically and experimentally by Bär[1]. With regard to velocity atomizers, various attempts have been made to calculate theoretically the droplet mixtures of this group, irrespective of the construction of the atomizer. This seems an impossible task, however, as the various designs have differences which are not apparent at first sight.

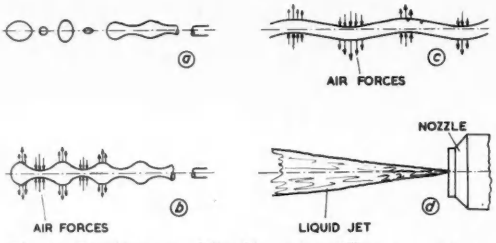

Fig. 1. **Breaking up of liquids under different conditions (see Table I).**

THE BREAKING UP OF LIQUID JETS

The various ways in which it is possible for a jet of liquid to break up into droplets are shown in Table I. The distinctions were originally defined by Weber[2] and Hänlein[3]. Subsequently, on the basis of Weber's classification and his own tests, von Ohnesorge[4] published a diagram in which the characteristic conditions are related to three different regions, separated by demarcation lines. This diagram is reproduced in Fig. 2.

The various regions overlap somewhat owing to initial disturbances, so that the demarcations are not in fact so sharply defined, but this diagram should serve to guard experimenters against carrying out tests in borderline regions which may lead to uncertain conclusions.

TABLE I. BREAKING UP OF LIQUIDS.

Type of Breaking up	Description	Region in Fig. 2
Dribbling	Fluid dribbles without forming a jet (Fig. 1a)	—
Jet-droplet formation, with or without air	Jet of liquid breaks up, owing to rotationally symmetrical vibrations (contractions and expansions) in the jet, due to initial disturbances in the nozzle; air forces increase the vibration amplitude (Fig. 1b)	I
Jet oscillation	Lateral oscillations of jet (without changes of jet section) cause "flailing" and breaking up (Fig. 1c)	II
Atomization	High-velocity jet ejected from the nozzle breaks up as a spray cone, with "disorderly" motion (Fig. 1d)	III

Most technical applications of the dispersion of liquid jets are situated in region III (atomization conditions). The breaking up of jets of liquid has been the subject of considerable theoretical and experimental work by numerous investigators, including Rayleigh[5], who investigated the case of a non-viscous liquid ejected from a vessel and breaking up owing to rotationally symmetrical vibrations. The breaking up occurs when the wavelength of the vibration becomes greater than the length of the periphery of the undisturbed jet of liquid.

The wavelength l_{opt} with the greatest amplitude is obtained in a first approximation as

$$l_{opt} = d\,\pi\,\sqrt{2} \quad \ldots \quad \ldots \quad (1)$$

where d = diameter [metres] of the undisturbed jet, and the corresponding damping exponent is

$$\mu_{opt} = \sqrt{\sigma/\rho_{fl}\,d^3} \quad [\text{sec}^{-1}] \quad \ldots \quad (2)$$

where σ = static surface tension of liquid [kg/m] relative to air and ρ_{fl} = mass density of liquid [kgsec^2/m^4]. Thus, for any jet of non-viscous liquid breaking up into droplets, the volume of the droplet is

$$V_{dr} = (\pi/4)\,d^2\,l_{opt} = \sqrt{2}\,\pi^2\,d^3/4 \quad [\text{m}^3] \quad \ldots \quad (3)$$

and this is independent of the surface tension. Weber[2] extended Rayleigh's theory to viscous fluids. He treated the case of a liquid jet which breaks up owing to rotationally symmetrical vibrations unaffected by air (steady jet or jet in a high vacuum). The optimum wavelength l_{opt} of the vibration of the droplet-forming liquid is obtained as

$$l_{opt} = \pi\,d\sqrt{2\,(1 + A)} \quad \ldots \quad \ldots \quad (4)$$

where $A = \sqrt{9\,\eta_{fl}^2/\sigma\,\rho_{fl}\,d}$, η_{fl} being the dynamic viscosity [kgsec/m^2] of the liquid. The vibration frequency is $f_{opt} = 1/l_{opt}$; the volume of the droplet is

$$V_{dr} = (\pi^2\,d^3/4)\,\sqrt{2\,(1 + A)} \quad \ldots \quad (5)$$

and the corresponding damping factor is $e^{\mu_{opt}t}$, with

$$\mu_{opt} = 1/[\sqrt{\rho_{fl}\,d^3/\sigma} + (3\,\eta_{fl}\,d/\sigma)] \quad \ldots \quad (6)$$

With increasing viscosity the wavelength and the volume of the droplet increase, while the frequency is reduced correspondingly.

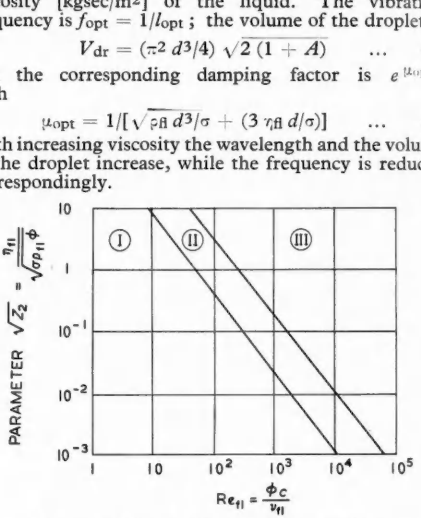

Fig. 2. **Characteristic conditions of the breaking up of liquid jets, referred to three different regions, according to von Ohnesorge[4] (see Table I).**

Weber also treated theoretically the case of droplet formation from a jet exposed to the influence of air. The air was assumed to be a non-viscous compressible fluid. In this case, it is no longer possible to obtain an explicit expression for the optimum wavelength. However, the calculation indicates that the influence of the air density ρ_a is very small, so that l_{opt} can be represented in the form

$$l_{opt} = \pi\,d\,\sqrt{2} + \text{const.}\,(\rho_a/\rho_{fl}) \quad \ldots \quad (7)$$

According to Hänlein[3] and von Ohnesorge[4], in the breaking up of liquid jets with a high outflow velocity there occurs a "random" atomization, which, in the opinion of Oguey[6], is mainly attributable to the internal turbulence of the jet. A non-dimensional characteristic "turbulence parameter" can be determined for the process:—

$$Z_1 = \sigma/(\rho_{fl}\,c^2\,d) \quad \ldots \quad \ldots \quad (8)$$

in which c = outflow velocity of the liquid [m/sec].

These considerations show that droplet formation in liquid jets involves forces due to surface tension, inertia, viscosity, and air movement. These forces are not all of the same importance. In particular, with strong internal movements (turbulence) of the liquid, the surface and inertia forces are predominant.

SIZE OF THE LARGEST DROPLET

An atomization process can be described as follows:—A jet of liquid at high velocity comes into contact with still air and is broken up or subdivided into masses of various sizes and shapes. The larger masses immediately break up further, whereas the smaller masses, owing to surface tension, contract into more or less spherical shapes. The subdivision thus produces droplets of various sizes. This mixture of droplets is slowed down in the air and yields the end-product of the atomization process.

It is possible to measure both the initial and the final conditions of the process. The jet initially coming into contact with air is characterized by its relative velocity,

temperature, material constants, etc. The end-product is also characterized by corresponding quantities. Such measurements, however, still require a certain amount of time and expense. It would be most desirable to be able to correlate theoretically the type of the droplet mixture obtained with the operating conditions.

It can be said that previous attempts to determine this theoretical correlation have not led to results which are applicable in practice. It is of interest to note in particular the following discrepancy :—Experimentally, no instance has been found of a marked dependence of the degree of atomization on air density. On the other hand, all the known theoretical formulae for calculating droplet size in atomization processes indicate an inverse proportionality law as the relation between droplet diameter and air density. An exception is the purely empirical formula of Nukiyama[7], which shows no dependence on air density, but which is not dimensionally correct.

This experimental fact that air density has practically no influence on atomization led Ackeret to consider that the breaking up of droplets follows laws similar to those valid for liquid jets. Tests have, in fact, shown that liquid jets break up[8] even in very low air densities (around 0·01 atm absolute), although admittedly much more slowly than with air at atmospheric pressure. However, in the latter case, the degree of atomization is affected only to an insignificant extent.

The problem is therefore to combine the forces occurring in the breaking up of a jet into characteristic parameters, in such a way as to obtain a stability criterion for the breaking up of droplets, which can subsequently be verified by experiments.

Let Φ_{max} denote the diameter of the largest droplet (in metres). The forces involved in the breaking up of droplets may be expressed as follows :—

Inertia force of liquid $\rho_{fl}\, c^2\, \Phi_{max}{}^2$.
Surface-tension force $\sigma\, \Phi_{max}$.
Viscosity force of liquid $\eta_{fl}\, c\, \Phi_{max}$.
Inertia force of air $\rho_a\, c^2\, \Phi_{max}$.

Tests by Hänlein have shown that high nozzle-exit velocities c are necessary for the atomization process. Thus, the breaking up of droplets is caused primarily by the internal turbulence in the droplet, and a measure of the intensity of this turbulence is provided by the ratio of surface-tension force to the inertia force. Hence, in analogy with eq. (8),

$$Z_1 = \sigma/(\rho_{fl}\, c^2 \Phi_{max}) \quad \ldots \quad \ldots \quad (9)$$

However, as droplet size also depends on the viscosity of the liquid, the breaking-up process must also be affected by a second parameter Z_2, which takes account of viscosity as a factor. According to Rayleigh and Weber (eqs. (3) and (5)), the volumes of a droplet of non-viscous and viscous fluid respectively can be expressed by the ratio of

$$(\pi^2\, d^3\, \sqrt{2}/4) \text{ to } (\pi^2\, d^3\, \sqrt{2}/4) \times \sqrt{1 + A} \quad (10)$$

for the breaking up due to rotationally symmetrical vibration of jets. The corresponding diameter ratio for spherical droplets is

$$\Phi_\eta/\Phi_o = \sqrt[6]{1 + A} \quad \ldots \quad \ldots \quad (11)$$

the diameters of the viscous and non-viscous droplet being denoted by η and o respectively. The parameter for the influence of viscosity should therefore be of the form

$$Z_2 = \eta_{fl}{}^2/(\sigma\, \rho_{fl}\, \Phi_{max}) \quad \ldots \quad \ldots \quad (12)$$

This parameter Z_2 was first introduced by Hänlein.

For the breaking up of liquid jets, and hence also of droplets (according to Ackeret's hypothesis), the criterion should include Z_2, which appears in the form $Z_2{}^{1/12}$ in Weber's theory. It has been proved experimentally that, even for freely falling droplets, there exists a criterion of stability, which contains the viscosity coefficient to this same power (1/12). Therefore, for atomization tests in vacuum it can be expected that the breaking-up criterion will be of the form

$$F = F\,(Z_1 \times Z_2) = \text{const.} \ldots \quad \ldots \quad (13)$$

If forces due to the presence of air also occur, their influence would need to be taken into account by means of a third parameter Z_3, representing, for instance, the ratio of the inertia forces of the air and of the liquid, so that

$$Z_3 = \rho_a/\rho_{fl}. \quad \ldots \quad \ldots \quad (14)$$

The first inclination might be to combine these parameters in the form of a product

$$Z_1{}^n\, Z_2{}^m\, Z_3{}^r = \text{const.} \quad \ldots \quad \ldots \quad (15)$$

as a condition for breaking up, but the subsequent discussion will show that this is not possible. Experimental evidence[1, 9] indicates that the maximum droplet diameter is approximately inversely proportional to c^2. Therefore, $n = 1$. From Weber's theory, it can be expected that $m = 1/12$.

From all the investigations previously mentioned, the influence of air is small; thus, r is so small that it may be assumed that Z_3 occurs as a linear function of ρ_a/ρ_{fl}. The result so far is then

$$Z_1\, Z_2{}^{1/12}\, Z_3 = \text{const.} \quad \ldots \quad (16)$$

Some further indications on the structure of this function can be derived by considering the following limiting cases :—

(1) When $\sigma = 0$, $\Phi_{max} = 0$, since the droplet is held together by surface tension.
(2) When $c = 0$, $\Phi_{max} \to \infty$; the conditions are then no longer those of atomization but of dribbling, for which other laws are valid.
(3) When $\eta_{fl} = 0$, $\Phi_{max} > 0$.
(4) When $\rho_a = 0$, $\Phi_{max} > 0$.

The following equation is a function fulfilling these limiting conditions :—

$$Z_1\, (1 + a_1\, Z_2)^{1/12} \times (1 - a_2\, Z_3) = K = \text{const.} \quad (17)$$

and this will be used, therefore, as a basis for further investigation. When the constants K, a_1, and a_2 are known, this relation enables the maximum possible droplet diameter Φ_{max} to be calculated from the physical constants of the two media and the velocity c at the beginning of droplet deformation.

From these considerations it follows that, in order to calculate Φ_{max} for an atomization process, it is necessary that the exit velocity (or the relative velocity) c should have a measurable value, and that this value should not decrease to an appreciable extent during the breaking-up process in which the droplet mixture is produced. However, only certain types of atomizers fulfil this condition. In non-rotating pressure atomizers, the jet is broken up gradually from the outside in such a way that the core portions are the last to break up into droplets. The jet velocity c relative to the nozzle orifice, prevailing at this instant, is lower than the exit velocity of the jet. As it is not easily measurable, Φ_{max} for this type of atomizer cannot be calculated with the aid of the simple quantities derived from operating conditions.

The determination of the constants of eq. (17) is possible only on an experimental basis. The atomization tests for this purpose should satisfy the above requirement that the velocity c is maintained appreciably constant and should also yield a large number of droplets of the maximum size.

These two requirements are best fulfilled by the rotating type of pressure atomizer. From the tests made by Bär[1] on atomizers of this type, it follows that K can be assigned a mean value of 0·000048. Moreover, a_1 has to be chosen in such a way that $(1 + a_1\, Z_2)^{1/12} \simeq a_1\, Z_2{}^{1/12}$. Therefore, put $a_1 = 10^6$.

On the basis of Weber's calculation of the influence of jet droplet formation on droplet size, it can be

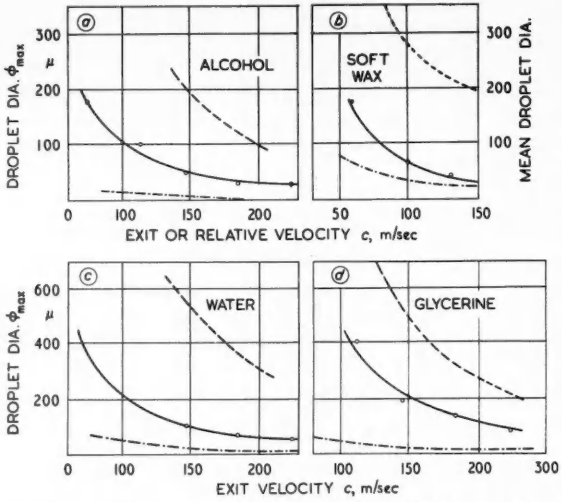

Fig. 3. **Stability curves for droplets of different liquids.**
(*a*), (*c*), (*d*)—Maximum droplet diameter Φ_{max} as a function of exit velocity *c*.
Full lines according to eq. (18); dotted lines according to Triebnigg[14]; chain-dotted lines according to Bär[1].
(*b*) Mean droplet diameter *Dm* as a function of exit velocity *c*.
Full line according to eq. (44); dotted line according to Merrington[13]; chain-dotted line according to Nukiyama[7].

assumed that $a_2 = 0{\cdot}5$. With these numerical values, eq. (17) can be re-written as

$$\frac{\sigma}{\rho_{fl} c^2 \Phi_{max}} \times \left(1 + 10^6 \times \frac{\eta_{fl}^2}{\sigma \rho_{fl} \Phi_{max}}\right)^{1/12} \times \left(1 - 0{\cdot}5 \frac{\rho_a}{\rho_{fl}}\right) = 4{\cdot}8 \times 10^{-5} \quad \ldots \quad (18)$$

According to eq. (18), the droplet diameter Φ_{max} is independent of air viscosity. This factor was found to have only a very slight influence on droplet size by Lewis[10] and Oschatz[11]. Lewis observed a somewhat finer atomization with decreasing air viscosity, whereas Oschatz found it to be somewhat coarser.

Eq. (18) can be regarded as a criterion for the breaking up of droplets and it can be used to calculate the diameter of the largest droplet. It requires the following conditions to be fulfilled :—

(1) It should be possible to measure the velocity *c* occurring at the beginning of the deformation of the droplet (relative to the nozzle orifice, or to the surrounding air for pressure atomization) at every point in the mixing chamber.
(2) Subsequent re-agglomeration of droplets should not occur in the dispersion chamber (situated after the mixing chamber and the diffuser).
(3) The atomization process should not be affected by a third atomizing medium (e.g., baffle plates).

The classification of types of atomizers already given is based on these considerations. It shows immediately that pressure atomizers with rotating nozzles and compressed-air atomizers in which liquid is injected in a plane perpendicular to the direction of air velocity fulfil these standard requirements, whereas this is not generally the case for pressure atomizers with stationary nozzles and compressed-air atomizers in which liquid is injected at any angle relative to the direction of velocity of the atomizing air.

Finally, it may be noted that, with the knowledge at present available, it is hardly possible to assess theoretically the complete interplay of forces which are of major importance in atomization. Nevertheless, it may be said that the initially formulated problem has been brought one stage further towards its general solution and that, provided that the above requirements are fulfilled, eq. (18) enables test results to be predicted over wide ranges of operating conditions. The improvement obtainable with eq. (18), as compared with previously existing formulae, is illustrated by the examples in Fig. 3, which includes stability curves for droplets of different liquids, according to Bär[1], Nukiyama[7], Merrington[13], and Triebnigg[14].

Droplet Characteristics

The Droplet-Number Distribution Curve :— The above considerations regarding the size of the largest droplet indicate that the initial velocity *c* determines the droplets of maximum size. For the smaller droplets, the velocity, and the other parameters in eq. (18), cannot be made directly responsible.

The statistical character of the frequency curves indicates that, before the droplet enters the dispersion chamber, an active and disorderly interchange of energy takes place (the droplets combine, break up again, and recombine). This "state of disorder," as it was called by Hänlein[3], is a phenomenon which was described in detail by Castleman[12], Merrington[13], and Lewis[10]. It is the first stage of atomization. The random movements necessarily lead to the generation of extremely large and extremely small droplets, both of which occur, however, in very small quantities.

In the atomization process, the final state can be determined only by considering an extremely large number of particles and taking the mean value of the distribution. This characterizes the "macro-condition," but this same condition can be obtained by means of very many different "micro-distributions." It appears to be characteristic of atomization processes that, in the diffuser section, the "macro-condition" may remain unchanged, although the "micro-distribution" is constantly changing; in this connection it may be said that all the successive micro-distributions are equally probable.

In the dispersion chamber, where, as previously stated, it is assumed that no further collisions should take place, the final macro-distribution of the droplet mixture is already nearly completed. In this chamber, only droplets of diameters Φ greater than Φ_{max} will be modified (i.e., will break up), so that the mixture in the diffuser section will also correspond practically to the final mixture.

(To be concluded)

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Problems of Supersonic Axial Compressors

By E. SCHNELL. (From *MTZ*, Vol. 16, No. 2, February 1955, pp. 42-46, 11 illustrations,)

THE pressure ratio attainable in an axial compressor stage is limited by the Mach number of the relative and absolute velocities in the blade cascade. In the subsonic compressor, when these velocities approach the speed of sound, compression shocks occur on the blade surfaces, causing a break-away of the flow and resulting in pressure losses. This fact limits the working range of the subsonic compressor. In the supersonic compressor, on the other hand, the compression shock is used to increase the pressure, but it requires a suitable design of the blade profiles to avoid a break-away of the flow behind the shock front.

The blade rows or cascades of an axial compressor form diffuser passages in which kinetic energy is converted into pressure energy by decreasing the relative velocity (impeller) or the absolute velocity (guide wheel). Thus, in the design of supersonic cascades, use can be made of the knowledge and experience obtained with supersonic diffusers.

NOTATION

A	mechanical equivalent of heat	τ	angle of flow relative to the compressor axis
a	speed of sound	θ	wave angle (direction of shock front)
a^*	critical flow velocity	*Subscripts :—*	
c	absolute velocity	0	steady-state condition (ahead of compressor)
F	flow cross-section	1	condition ahead of shock front or at impeller inlet
g	acceleration due to gravity	2	condition behind shock front or the impeller inlet
H	delivery head	n	perpendicular to a shock front
M	Mach number	t	tangential to a shock front
p	(static) pressure	tot	overall condition (steady-state condition)
R	gas constant	ax	axial component
T	absolute (static) temperature	u	peripheral component
u	peripheral velocity		
w	relative velocity		
β	angle of flow relative to cascade axis (peripheral direction)		
δ	angular deflection of supersonic flow		
$\varkappa$	ratio of specific heats		

FLOW PHENOMENA IN A SUPERSONIC DIFFUSER

Whereas subsonic flow generally occurs with gradual decreases in velocity and increased pressures, the slowing down of a supersonic flow always gives rise to discontinuities, in which the pressure and the (static) temperature vary abruptly. The discontinuity forms a shock front which, according to the boundary conditions, can be either normal or at an angle to the direction of flow. Thus, there is either a normal or an oblique compression shock.

Fig. 1 shows the thermodynamic changes of state in a normal compression shock for an ideal gas of constant specific heat with $\varkappa = 1{\cdot}40$ (air). As can be seen from the variation of the curve of Mach numbers after the shock front (M_2), in such a compression shock the flow velocity is always reduced from a supersonic to a subsonic value. The magnitude of the velocity and pressure jump becomes greater when the Mach number of the upstream flow velocity (M_1) is increased. In contrast with subsonic flow, however, the velocity drop in a compression shock is not without some losses, even for frictionless flow. The fluid passing through the shock front is subjected to an increase in entropy, which is represented in Fig. 1 by the pressure ratio $(p_2/p_1)_{tot}$ relative to the overall condition. If, in analogy with subsonic diffusers, a " shock efficiency " is defined as

$$\eta_{sh} = 1 - \frac{\Delta p_{tot}}{\Delta p} = 1 - \frac{p_{1tot}}{p_1} \times \frac{1 - (p_2/p_1)_{tot}}{(p_2/p_1) - 1} \qquad (1)$$

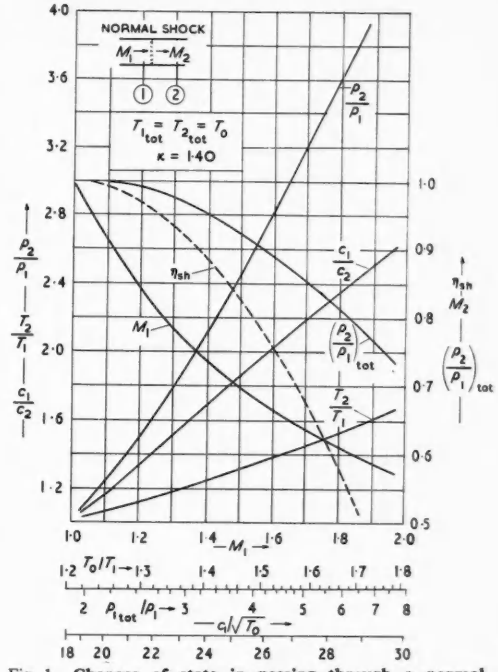


Fig. 1. **Changes of state in passing through a normal compression shock.**

then from Fig. 1 it can be found that, up to Mach numbers $M_1 \cong 1{\cdot}55$, this efficiency reaches values which are fully comparable with the efficiencies of good subsonic diffusers.[1] However, with higher velocities in the upstream section, the efficiency of the normal shock falls off rapidly.

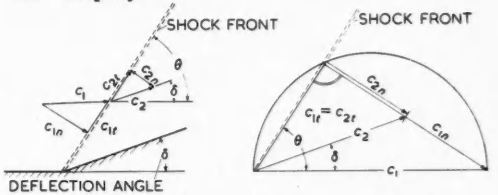


Fig. 2. **Relations for an oblique compression shock.**

The oblique compression shock is produced by a concave-corner deflection of the supersonic velocity. In contrast with the normal compression shock, therefore, the oblique shock requires a change in direction as well as in cross-section of the flow channel. If the velocity c_1 ahead of the shock is resolved into a component perpendicular to the shock front (Fig. 2),

$$c_{1n} = c_1 \sin \theta \qquad \ldots \quad \ldots \qquad (2)$$

and a tangential component in the direction of the shock front

$$c_{1t} = c_1 \cos \theta \qquad \ldots \quad \ldots \qquad (3)$$

then, from considerations of momentum, it follows that

$$c_{1t} = c_{2t} = c_t \qquad \ldots \quad \ldots \qquad (4)$$

[1] As the flow through the shock is associated with an abrupt reduction in velocity, in the above comparison frictional losses in the supersonic diffuser are not considered.

Therefore, only the perpendicular component is altered, and the conditions for the normal compression shock are also applicable to the perpendicular component in this case.

In considering oblique shocks it is convenient to distinguish between two cases, i.e., (1) the shock front forms an angle $\theta < 60$ deg. with the upstream direction of flow. Then, the supersonic character of the flow is also maintained behind the shock front, although the perpendicular component c_{2n} has a value which is below that of the local speed of sound. This has been termed a "directional shock." (2) For $\theta > 70$ deg., on the other hand, the upstream velocity is slowed down to a subsonic value. This is a "pressure shock." Admittedly, the pressure shock produces higher pressure conditions than the directional shock, but it is also associated with a much higher pressure loss. Moreover, as in the normal compression shock, there is the additional danger of a break-away of the boundary layer. For $\theta \simeq 65$ deg., the maximum angle of deflection δ_{max} obtainable with a specified Mach number M_1 is reached. The downstream velocity in this case is approximately equal to the local speed of sound. For angles of bends $\delta > \delta_{max}$, the requirements for the oblique compression shock can no longer be fulfilled, and a "detached" compression shock is obtained, which also leads to considerable losses.

Where fairly strong compression shocks occur, there is always the danger of a break-away of the boundary layer behind the shock front, owing to the sudden rise in pressure. Such flow separations, however, can be avoided, for instance by an acceleration of the flow immediately behind the shock front. Thus, if the velocity behind the shock front is subsonic (normal shock), the subsequent cross-section should be made narrower. Protection against a separation of the boundary layer will be increased by using a value as large as possible for the ratio F_1/F_{min} of the cross-sections (Table 1). The upper limit is this respect is obtained when the local speed of sound is reached in the minimum cross-section F_{min}. Assuming a normal shock at the diffuser inlet and adiabatic expansion between F_1 and F_{min}, the maximum cross-sectional ratio for air ($\varkappa = 1{\cdot}40$) will in this case be

$$\frac{F_1}{F_{min}} = \frac{(p_1/p_2)_{tot}}{M_1} \times \left[\frac{1 + 0{\cdot}20\, M_1^2}{1{\cdot}20}\right]^3 \quad \ldots \quad (5)$$

In this relation $(p_2/p_1)_{tot}$ is the overall pressure loss in the normal shock at the inlet (Fig. 1). This relation is represented numerically in Table 1 and is compared with the values for cross-sectional ratios of a series of NACA supersonic diffusers. The reference value chosen in each case is the smallest Mach number which still ensures stable operating conditions in the corresponding diffuser (Fig. 4), and it can be assumed that the condition for the development of a normal compression shock at the diffuser inlet is fulfilled to the best possible degree with this M_1-value.

From the above considerations, some important indications can now be derived for the design of ultrasonic diffusers and blade cascades. The invariably shock-like transition from the supersonic velocity into the subsonic region should take place at supersonic Mach numbers which are not excessively high ($M_1 < 1{\cdot}50$). If the upstream velocity exceeds this value, it will then be necessary to use a combined system of one or more directional shocks followed by a final normal shock. The directional shock in this case reduces the upstream velocity to a supersonic speed of smaller Mach number, and the final normal shock then leads this velocity to a value below the speed of sound. If shocks of greater magnitude occur, or if pressure conversion is to be obtained only by means of a normal shock, then the flow immediately behind the shock front should again be accelerated, to avoid flow separation.

Besides reducing the break-away tendency, with sufficiently high Mach numbers the combination of directional shocks and normal shock also results in a substantial improvement of the actual shock efficiency. Fig. 3 shows as an example the flow conditions and shock efficiencies obtainable with the combination of a directional shock and a normal shock, with $\varkappa = 1{\cdot}40$.

NACA tests on supersonic diffusers confirm the above considerations. Fig. 4 shows schematically the testing arrangement used by NACA, as well as the more important test results. The indicated overall pressure ratios include the losses from the throat of the supersonic nozzle up to the diffuser exit. The individual losses due to various factors are also plotted in Fig. 4, for a series of measurements with $\tau = 2\delta = 18$ deg. In these results, the nozzle-loss coefficient has been taken as $\xi = 2g\,\Delta h_{nozzle}/c_1^2 = 0{\cdot}035$. For the losses in the subsonic portion of the diffuser a linear decrease of the subsonic diffuser efficiency was

TABLE I. MAXIMUM CROSS-SECTIONAL RATIOS OF A SUPERSONIC DIFFUSER WITH A NORMAL COMPRESSION SHOCK AT THE DIFFUSER INLET.

M_1	1·1	1·2	1·4	1·6	1·8	2·0	2·2	2·4
NACA values, F_1/F_{min}	—	1·02	1·06	1·12	1·18	1·22	1·27	1·30
Adiabatic expansion, F_1/F_{crit}	1·01	1·04	1·12	1·26	1·44	1·70	—	—

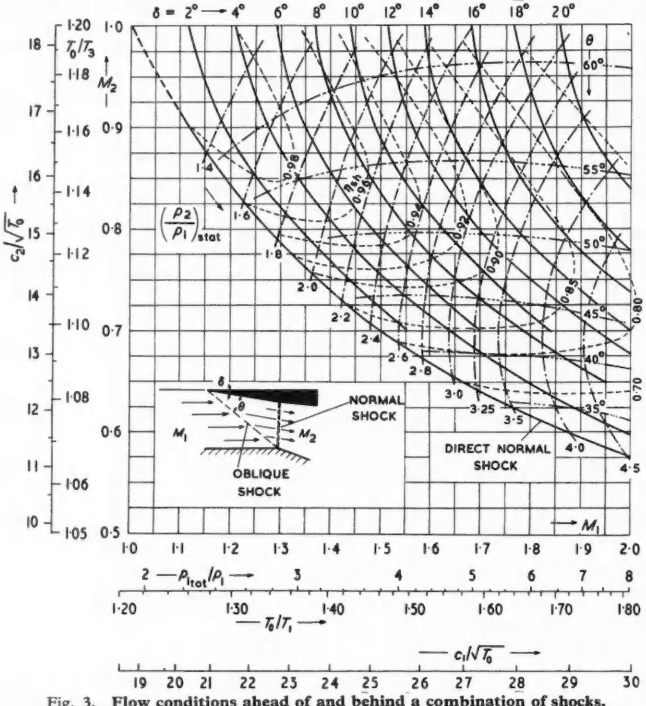


Fig. 3. **Flow conditions ahead of and behind a combination of shocks, consisting of one directional shock and one normal shock.**

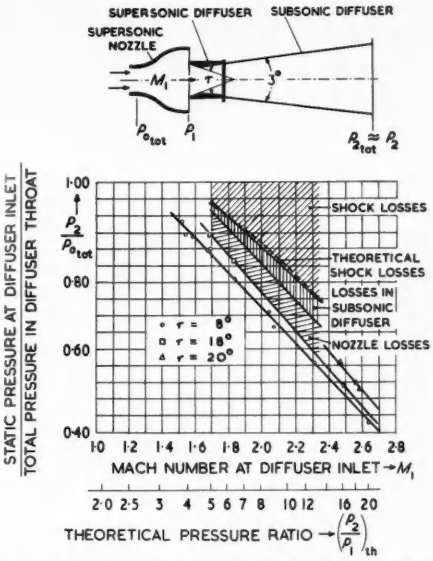


Fig. 4. **Schematic testing arrangement and pressure losses for NACA supersonic diffusers.**

assumed from $\eta_i = 0{\cdot}90$ at $M_1 = 1{\cdot}8$ to $\eta_i = 0{\cdot}70$ at $M_1 = 2{\cdot}5$. This seems reasonable if it is considered that the contribution of the normal compression shock in a shock combination becomes greater with increasing values of M_1 and that, therefore, flow separations can develop at the inlet in the subsonic portion. If the calculated losses of the nozzle and subsonic diffuser are subtracted from the measured overall losses, the resulting curve gives an indication of the losses in the supersonic portion of the diffuser. For comparison, the theoretical shock efficiency is also plotted. The two curves differ only slightly from each other, so that it can be assumed that, in the supersonic portion of the diffuser, no substantial frictional losses occur, apart from the actual shock losses.

Supersonic Compressors

Supersonic compressors can be classified into four basic types, according to the position in the compressor at which supersonic velocity occurs :—

(a) The relative velocity at the inlet into the impeller is situated in the supersonic region. In the impeller the flow velocity is decreased to subsonic values, so that the exit from the impeller occurs with a subsonic relative velocity. The guide wheel behind it is designed as a purely subsonic system.

(b) The impeller is built as a subsonic cascade. The absolute inlet velocity into the guide wheel situated behind it is higher than the speed of sound, and the guide-wheel cascade is designed as a supersonic diffuser.

(c) Both the relative velocity at the impeller inlet and the absolute velocity into the subsequent guide-wheel inlet are supersonic. The impeller and guide-wheel blade systems are designed as supersonic diffusers.

If the compressor is required to have an axial exit, then with arrangements (b) and (c) very great flow deflections have to be obtained in the impeller, simultaneously with considerable reductions in velocity. Experience shows, however, that flows around bends of this type are associated with high losses. Moreover, the supersonic inlet of the guide wheel is situated downstream of the impeller, and, owing to boundary-layer development in the impeller passages, the flow should be regarded as unstable. As a result satisfactory operation of the supersonic impeller may sometimes be doubtful.

(d) The relative velocities of the impeller are supersonic both at the inlet and at the exit. The impeller is a supersonic cascade.

In compressors of this type, the supersonic impeller should not be constructed as a supersonic diffuser, but should be designed according to the requirements for supersonic aerofoil sections. As the entire pressure rise of a compressor stage is the sum of the pressure rises in the impeller and the guide wheel, it is easily seen that a design of this type will yield smaller pressure ratios than those obtained with arrangement (a), although under certain conditions it may give higher efficiencies.

For the purpose of obtaining as high a pressure rise per stage as possible and in view of its fully satisfactory flow conditions in the supersonic region of the compressor, arrangement (a), in which only the relative velocity at the inlet into the impeller is supersonic, appears to be the more favourable solution for a supersonic compressor, at least in the first phases of development of compressors of this type. This arrangement will therefore be studied more closely in the following.

In order to obtain high pressure ratios and delivery heads, an effort should be made to reach as high a value as possible for the relative velocity at the inlet into the impeller. In an axial compressor without an inlet guide wheel, this is obtained as the vector sum of the subsonic inlet velocity c_m and the peripheral velocity u of the impeller. The peripheral velocity, however, for mechanical reasons, is limited to values in the range of about 400 to 420 m/sec.

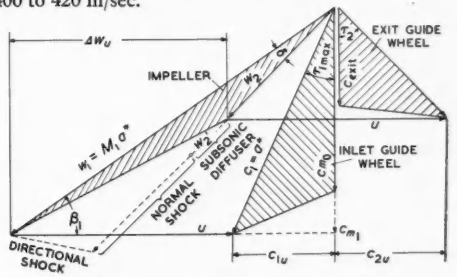


Fig. 5. **Velocity diagram of a supersonic compressor with supersonic velocity at the impeller inlet.**

As can be seen from Fig. 5, with specified values of c_m and u, it is possible to increase the relative velocity w_1 by interposing ahead of the impeller an inlet guide-wheel arrangement which will produce a moment of momentum with a direction opposite to that of impeller rotation. With this arrangement, however, owing to the boundary layer at the blades of the inlet guide wheel, some irregularities will be produced in the flow ahead of the impeller but, because the flow is accelerated in the inlet guide wheel, these disturbances will not be so pronounced as, for instance, behind a velocity-reducing cascade.

According to the requirement specified above, supersonic velocity should occur only at the impeller inlet; this limits the magnitude of the moment of momentum at the impeller inlet to the value of the critical velocity at the exit from the inlet guide wheel.[2] With adiabatic expansion, the ratio of the critical cross-section (exit cross-section of an inlet guide-wheel passage) to the inlet cross-section, in the case of air, is

$$\frac{F_{crit}}{F_0} = M_0 \left[\frac{1{\cdot}20}{1 + 0{\cdot}20\, M_0^2} \right]^3 \quad \ldots \quad \ldots \quad (6)$$

where M_0 is the Mach number of the axial upstream velocity of the inlet guide wheel. With a constant blade

[2] The development of the inlet guide wheel as a supersonic nozzle would also have resulted in difficulties in the starting of the compressor.

height for the inlet guide wheel, according to Fig. 6,

$$\cos \tau_1 \simeq F_{\min}/t = F_{\text{crit}}/F_0,$$

and the maximum angle of the moment of momentum of the inlet guide wheel is obtained approximately as

$$\cos \tau_{1\max} = M_0 \left[\frac{1{\cdot}20}{1 + 0{\cdot}20\, M_0{}^2} \right]^3 \quad \ldots \quad (7)$$

To conform with the required condition, in this case

$$c_1 = a^* = \sqrt{2\, \varkappa\, g\, R\, T_0/(\varkappa - 1)} = 18{\cdot}3 \sqrt{T_0}.$$

Thus, relative velocity at the inlet into the impeller is

$$w_1{}^2 = c_{m1}{}^2 + (u + c_{1u})^2 = a^{*2} \left[\cos^2 \tau_{1\max} + \{ (u/a^*) + \sin^2 \tau_{1\max} \}^2 \right]$$

Now, $M_1 = w_1/a_1 = w_1/a^*$; hence, with specified values of peripheral and inlet velocity, the maximum attainable Mach number at the impeller inlet is

$$M_1 = \left[\cos^2 \tau_{1\max} + \{ (u/18{\cdot}3 \sqrt{T_0}) + \sqrt{1 - \cos^2 \tau_{1\max}} \}^2 \right]^{\frac{1}{2}} \quad \ldots \quad \ldots \quad (8)$$

The supersonic relative velocity $w_1 = M_1 a^*$ at the impeller inlet now has to be reduced to a subsonic value w_2 at the outlet. This can be achieved by designing the supersonic impeller cascade in accordance with the experience gained with supersonic diffusers.

Fig. 6.

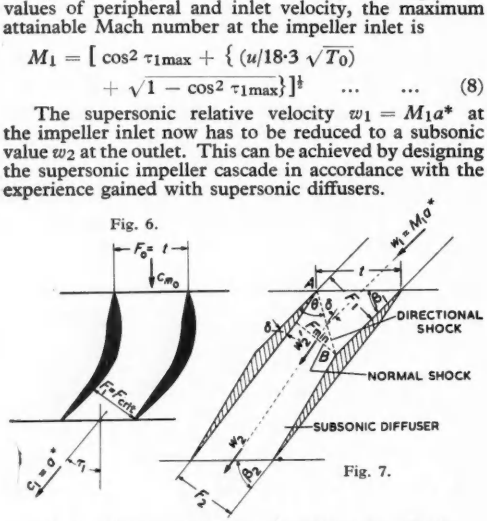


Fig. 7.

Fig. 6. **Flow conditions at the inlet guide wheel.**
Fig. 7. **Blade passage of a supersonic cascade.**

Fig. 7 shows a blade passage of a supersonic cascade developed on the basis of these considerations and providing the entry with a simple combination of directional shock and normal shock. As a result of directional shock, flow is deflected through an angle δ. Normal shock will occur in the narrowest cross-section $F_{\min}$ of the passage. With specified values for M_1 and δ, the flow conditions behind the normal shock (M_2' or w_2' in Fig. 7) can be read from Fig. 3. In the subsequent subsonic portion of the cascade there is a further decrease in flow velocity, owing to the widening of the cross-section from $F_{\min}$ to F_2. It is advisable not to increase the curvature of the subsonic diffuser any further, in order to avoid additional secondary flows.

With the relative exit velocity w_2, the change of the peripheral component Δw_u will be, according to Fig. 5,

$$\Delta w_u = w_1 \cos \beta_1 - w_2 \cos (\beta_1 + \delta);$$

or

$$\frac{\Delta w_u}{\sqrt{T_0}} = 18{\cdot}3\, M_1 \cos \beta_1 - \frac{w_2'}{\sqrt{T_{R\text{tot}}}} \times \sqrt{\frac{T_{R\text{tot}}}{T_0}} \left(\frac{w_2}{w_2'} \right) \cos (\beta_1 + \delta) \quad \ldots \quad (9)$$

where

$$\cos \beta_1 = \sqrt{1 - \sin^2 \beta_1} = \sqrt{1 - (\cos^2 \tau_{1\max}/M_1{}^2)} \quad (10)$$

The value of $w_2'/\sqrt{T_{R\text{tot}}}$ as a function of M_1 and δ can be taken from Fig. 3. $T_{R\text{tot}}$ is the overall temperature for the relative velocity corresponding to the Mach number M_1. It can be related to the overall temperature T_0 ahead of the compressor inlet, as follows :—

$$\frac{T_{R\text{tot}}}{T_0} = \frac{T_{R\text{tot}}}{T_1} \frac{T_1}{T_0} = \frac{1 + \frac{1}{2}(\varkappa - 1)\, M_1{}^2}{1 + \frac{1}{2}(\varkappa - 1)} = \frac{1 + 0{\cdot}20\, M_1{}^2}{1{\cdot}20} \quad \ldots \quad \ldots \quad (11)$$

w_2/w_2' is the velocity ratio in the subsonic diffuser.

By means of these relations and Euler's equation for flow in turbines, the theoretical delivery head of the compressor is obtainable as

$$H_{\text{th}} = \frac{u_2\, c_{2u} + u_1\, c_{1u}}{g} = \frac{T_0}{g} \times \frac{u}{\sqrt{T_0}} \times \frac{\Delta w_u}{\sqrt{T_0}} \quad (12)$$

The adiabatic delivery head and hence the total pressure ratio attainable with such a supersonic compressor stage can be derived from eq. (12) after subtracting the losses occuring in the individual cascades. For this purpose, it may be assumed that the inlet guide wheel has an efficiency of 90%.[3] The shock losses in the supersonic portion of the impeller can be taken from Fig. 3, while the efficiency of the subsequent subsonic portion can be estimated (on the basis of Fig. 4) as about 80%. In view of the non-uniform flow conditions which are likely to occur after the impeller, an efficiency of only about 75% can be expected for the exit guide wheel situated behind the impeller.

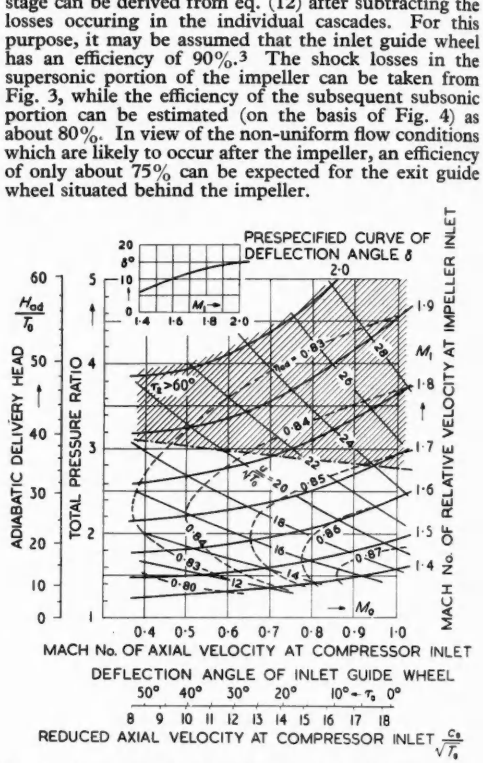

PRESPECIFIED CURVE OF DEFLECTION ANGLE δ
ADIABATIC DELIVERY HEAD
TOTAL PRESSURE RATIO
MACH No. OF RELATIVE VELOCITY AT IMPELLER INLET
MACH No. OF AXIAL VELOCITY AT COMPRESSOR INLET
DEFLECTION ANGLE OF INLET GUIDE WHEEL
REDUCED AXIAL VELOCITY AT COMPRESSOR INLET

Fig. 8. **General design chart for a supersonic compressor, with supersonic velocity at the impeller inlet.**

Fig. 8 is a general design chart for a supersonic compressor of the type considered and has been calculated in accordance with these considerations. The deflection angle δ in this chart is related to the Mach numbers M_1 corresponding to the optimum values from Fig. 3. In the shaded portion of the diagram, the inlet angle of the absolute velocity into the exit guide wheel is $\tau_2 > 60$ deg. Deflections of this magnitude, however, can no longer be obtained with a simple subsonic velocity-reducing cascade, so that, for working points in the shaded region, an exit guide wheel with specially designed blading should be provided; alternatively, the exit guide wheel can be dispensed with altogether and a volute diffuser arranged behind the impeller, as is customary with radial compressors.

[3] In the derivation of the maximum deflection in the inlet guide wheel, in contrast with the above, the calculation was based on an adiabatic expansion, for the sake of simplicity.

Exhaust-Valve Corrosion in Petrol Engines

By C. H. ALLEN and M. J. TAUSCHEK. (From *Automotive Industries*, Vol. 112, No. 11, June 1, 1955, pp. 52-55, 116, 118, 10 illustrations.)

THE fact that exhaust valves in petrol engines should corrode is not difficult to understand when the chemical environment in which they operate is examined. The combustion of a typical motor gasoline will yield appreciable quantities of free oxygen, lead, bromine, chlorine, and sulphur in the exhaust gases, plus lesser amounts of many other materials. It should also be remembered that these exhaust gases come in contact with the valves while they are very hot, and it is not inconceivable that the surface temperatures on some parts of the valve can exceed 2000° F. In passenger-car engines the temperature at the valve head, where it is exposed to the gases in the combustion chamber, averages about 1200° F, whereas on the underhead area, where the valve is in the path of the exhaust-gas stream, the temperatures reach 1300° F. The situation is more severe in heavy-duty engines, and temperatures here may well exceed 1600° F. There is considerable variation in valve temperatures between engines of different designs, and this may help to explain why valve corrosion is more of a problem in some engines than in others.

Typically, valves burn or fail through corrosion of the seating face where they close against the valve seat. Corrosion here is particularly serious, inasmuch as such corrosion interferes with the seal and thus allows combustion gases to leak past the valve face. This leakage markedly raises the valve-head temperature, in some instances as much as 300 to 400° F, and thus accelerates the corrosion already occurring. Finally, the reaction becomes so rapid that the valve is unable to close off the combustion chamber effectively and the engine will no longer operate satisfactorily.

Other types of corrosion can also occur on exhaust valves. Corrosion of the top of the valve head is frequently encountered, but this corrosion is not as serious as face corrosion, inasmuch as it does not interfere with the functioning of the valve. Corrosion can also occur on the stem portion of the valve. Corrosion of this sort, if unchecked, can lead to failure of the valve through breakage at the corroded area and can subsequently cause a great deal of damage to the engine. Fortunately, failures of this type are not frequent, but the fact that they do occasionally occur must be recognized. Another form of corrosion occurs on faced exhaust valves. In this type of valve construction, a highly corrosion-resistant material is welded to the valve base material at the seat face in order to avoid some of the face corrosion described previously. Sometimes, accelerated corrosion will occur at the juncture between the two materials. Such corrosion preferentially attacks the valve base material and weakens the support behind the welded layer. Eventually, such corrosion will cause distortion and cracking of the valve face.

It is particularly difficult to determine just what elements in the exhaust stream cause valve corrosion to occur. It is known from experience that tetraethyl lead plays a part, but not all corrosion can be attributed to lead. Other elements, such as sulphur, may have a marked influence on corrosion. Then, too, any free oxygen in the exhaust-gas stream will accelerate oxidation of the valve steels. Deposit-forming elements in the fuel or lubricating oil can also influence corrosion by forming deposit layers between the valve and the seat. These deposits may lead to solid-state reactions which induce valve-face corrosion. Again, local ruptures in the deposit layers permit combustion-gas leakage to occur. Such leakage raises the valve temperature and has an important effect in accelerating valve corrosion.

It is necessary in developing suitable alloys for use in exhaust valves to have some sort of a laboratory bench test which can be used for screening purposes.

TABLE I. PERCENTAGE ANALYSIS OF VALVE-STEEL ALLOYS.

Type	C	Mn	Si	Cr	Ni	Fe	N_2	Others
3140	0·4	0·8	0·3	0·7	1·3	Bal.	—	—
XB	0·8	0·4	2·0	21·0	1·5	Bal.	—	—
SIL. 1	0·5	0·4	3·3	8·5	—	Bal.	—	—
XCR	0·4	1·0	1·0	23·5	5·0	Bal.	—	2·8 Mo
SIL. 10	0·4	1·1	2·9	19·0	8·0	Bal.	—	—
21-12 N	0·2	1·3	1·0	21·0	11·5	Bal.	0·18	—
21-4 N	0·6	9·0	0·2	21·0	4·0	Bal.	0·40	—
TPM	0·1	2·0	0·1	15·7	Bal.	6·0	—	3·0 Ti

A special test procedure, which measures the resistance of the material to corrosion in molten lead oxide, has been devised for this purpose, and all the valve alloys in current use have been subjected to this test, in which a sample of the material is placed in a crucible with lead oxide and heated to 1675° F for one hour. The weight loss of the specimen is then determined, and this loss is used as a means of expressing the relative corrosion resistance of the alloy. This test does not consider the effects of any bromine and chlorine present in the exhaust gases, nor does it concern any of the other elements ordinarily found in petrol. Nevertheless, experience has shown that it correlates fairly well with tests conducted in engines and therefore has a certain amount of usefulness in developing new valve alloys. Naturally, however, it should be pointed out that the final proof can be obtained only from actual engine tests, since so many variables are encountered in connection with engine design, the fuel, and the lubricant.

SAE-3140 steel (see Table I), frequently used for intake valves in engines, illustrates how a conventional low-alloy steel reacts in this test, the weight loss in this case being more than 110 grams/dm²/hr, as compared with, for instance, about 50 for SIL. 1, 30 for SIL. 10, and less than 3 for TPM.

Silcrome No. 1 and Silcrome XB are alloys which were widely used in engines prior to the large-scale use of tetraethyl lead, and still find application in equipment with valves operating at moderate temperatures. Silcrome XCR is a phase-hardening steel developed to obtain optimum physical properties in the valve structure. 21-12N, Silcrome 10 N, and 21-4 N are austenitic steels, designed to obtain high hot strength. The nickel-base alloy TPM is used for aircraft valves.

It should be pointed out that, with the exception of the 21-4 N and the TPM alloys, in the design of which lead-corrosion resistance was of paramount importance, none of these alloys was designed primarily for corrosion resistance. In this connection, the analyses of these materials given in Table I shows what has been done to improve corrosion resistance. It should be noted that the high silicon contents advocated in the early valve steels have been drastically reduced in the case of 21-4 N and TPM. It is only recently that the

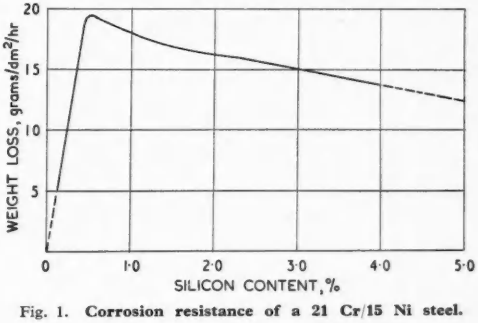


Fig. 1. **Corrosion resistance of a 21 Cr/15 Ni steel.**

effects of silicon, as well as of other low-concentration elements, have been recognized.

The influence of silicon in the typical 21 Cr/15 Ni austenitic valve steel shows that relatively low concentrations of silicon can have a deleterious effect on corrosion resistance (Fig. 1). Silicon of 0·5% produces the most rapid corrosion of the steel, whereas reductions in the silicon content drastically reduce the corrosion rate. Increasing the silicon concentration above 0·5% also reduces the corrosion rate, but to a lesser extent. The variation in corrosion rate with silicon above this concentration is small, however, and it is easy to appreciate why the true effects of silicon remained clouded for many years.

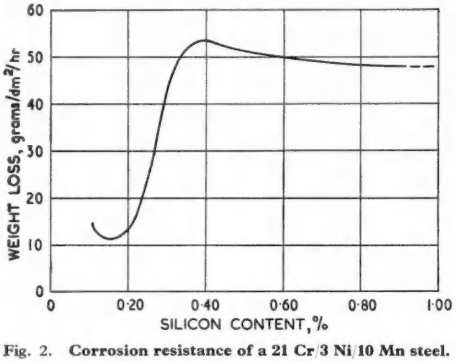


Fig. 2. **Corrosion resistance of a 21 Cr/3 Ni/10 Mn steel.**

Austenitic valve steels using manganese in place of nickel have received a good deal of attention. The effect of silicon in these steels is similar to that in the chrome-nickel steel. Comparing the corrosion rates of the chrome-nickel and chrome-manganese steels, it appears that nickel and manganese are interchangeable. Other experiments have shown that the effects of these two elements are additive, and that improvements in corrosion resistance can be attained by means of manganese additions up to about 10% to the chrome-nickel alloys. Because of factors relating to the processing of valve alloys and their physical properties, these chrome-nickel-manganese austenitic steels appear to be optimum. The effect of silicon in such steels is similar to that for the chrome-nickel and chrome-manganese alloys (Fig. 2), and low silicon contents are desirable for best corrosion properties.

Chrome-nickel-molybdenum and chrome-nickel-cobalt alloys have been investigated, although the latter have not achieved commercial importance. Molybdenum is a valuable strengthening agent, but in high concentrations has a tendency to oxidize. The objection to cobalt is purely one of economics, since cobalt has a pronounced effect in reducing the corrosion rate.

The nickel-base alloys are rapidly replacing the alloy steels in aircraft-valve applications. In developing these alloys, variations in the nickel-iron content were investigated (Fig. 3). These results show that nickel is effective in reducing the corrosion rate up to very high concentrations. Some increase in corrosion appears to take place with nickel concentrations over 60%, but this may have been caused by variations in the impurities. These data were obtained before the effects of silicon, aluminium, manganese, and titanium were fully recognized. Later work showed that silicon and aluminium both had a deleterious effect. Magnesium up to about 3% improved the corrosion resistance, and titanium also caused some improvement.

The TPM alloy currently used for aircraft valves has given a very creditable account of itself, and one engine model has reduced valve failures by a factor of seven.

Table II. Percentage Analysis of Valve-Facing Alloys.

Type	C	Mn	Si	Fe	Cr	Ni	W	Co
Stellite 6	1·05	0·06	1·21	2·0	27·6	—	4·25	Bal.
Stellite F	1·6	0·25	1·25	—	24·0	24·0	12·5	37·0
X-782	2·0	—	—	4·0	25·0	60·0	8·5	—
Endurite	2·0	—	1·0	8·0	29·0	39·0	13·15	10·0
Nichrome	0·2	0·94	0·21	0·8	20·25	77·1	—	—

A type of valve construction frequently employed for heavy-duty engines incorporates a seat of welded material puddled on the valve face. In this way optimum corrosion and hardness properties for the valve seating surface can be obtained. Special alloys have been developed for this purpose (Table II). These alloys all have high chromium, cobalt, and nickel contents, to achieve corrosion resistance. The tungsten is used primarily as a hardening agent. The corrosion resistance of these materials is uniformly good and superior to that of all commercial valve steels except TPM.

Alloy X-782 is of particular interest. This alloy is used to coat the seats and heads of some aircraft valves made from TPM. This coating imparts additional pitting resistance to the valve, even though the laboratory test indicates that TPM is more corrosion-resistant than X-782.

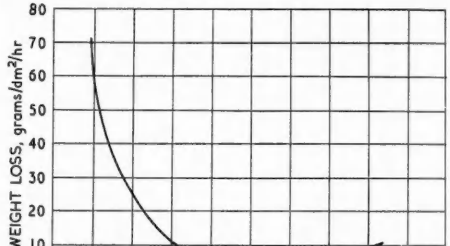


Fig. 3. **Corrosion resistance of a steel containing 20% Cr, 0·15% C, and nickel and iron, as shown.**

It should be pointed out that there are other ways of reducing exhaust-valve corrosion than by controlling the material analysis alone. One of the most significant developments in this respect has been the widespread use of valve rotators. These devices cause the valve to turn, and function by knocking off the deposits forming on the valve stem and face. This improves the gas seal, lowers the valve temperature, and thus retards valve corrosion. Engine tests have consistently shown valve-life improvements of from two to five times, and most heavy-duty engines now use valve rotation in one form or another.

Another recent development is the use of protective coatings. In one such process, a coating of pure aluminium is applied to the valve by means of a hot dip or metallizing process. The aluminium reacts with the iron in the valve steel to form a complex compound which is extremely corrosion-resistant. Engine tests with this coating on XCR valve steel have shown improvement in valve life of from two to four times.

Much can still be accomplished in reducing exhaust-valve corrosion. Although steels of conventional forging analyses have been fairly well explored, new processing techniques offer considerable promise. Vacuum melting is being investigated, and early results indicate that improved corrosion resistance can be obtained by this method. The casting of valves offers another alternative. By this method, highly alloyed materials impractical for forging can be handled. Composite valves of various materials and protective coatings are also being investigated.

British Industrial Developments

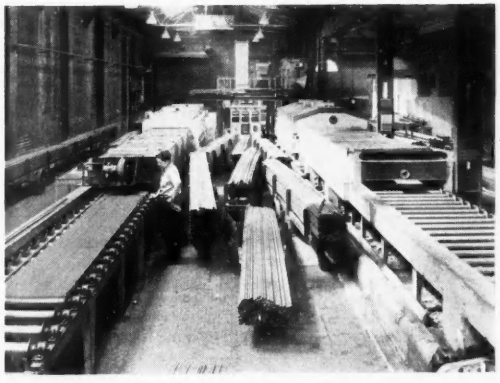
Electric Roller-Hearth Furnace

A new electrically heated roller-hearth furnace for annealing brass tubes, designed and installed by G.W.B. Furnaces Limited, of Dudley, has recently been put into production by the Yorkshire Copper Works Limited. Designed to treat tubes from $\frac{3}{4}$ up to 6 in. in diameter, in lengths up to 28 ft, the new furnace has an output of $1\frac{1}{2}$ tons of tubes per hour at 650° C, obtained with an electrical rating of 225 kW arranged in three independent automatically controlled zones.

The heating chamber is 20 ft long × 3 ft 9 in. usable width, and is suitable for accommodating charges up to 6 in. in height. The heating zones are 5 ft long in zones 1 and 2, while zone 3 is 10 ft long. A water-jacketed cooling chamber, 23 ft 6 in. long, is fitted at the exit end of the heating portion of the furnace, so that a gradual cooling rate of the charge is achieved, giving the desired mechanical properties to the charge. In order to obtain a degree of heat balance from one end of the unit to the other, and to cut down excessive end heat losses, an entrance vestibule, 1 ft 6 in. in length, is provided. These balanced conditions would also tend to reduce protective-atmosphere losses, should this form of charge protection be utilized. Heating is provided in the form of heavy nickel-chromium strip fitted in the roof and hearth of the heating chamber. The heating elements in the roof are carried on nickel-chromium hooks, while those in the hearth are supported on specially moulded refractories.

All rollers throughout the installation, including the 30-ft loading table, are power-driven. Generally, all rollers are at a pitch of 1 ft, except in the heating chamber itself, and where otherwise subjected to heat, in which case they are at a pitch of 6 in., in order to give maximum support to the brass tubes when at elevated temperatures. The rollers in the hot portion of the furnace are of a heat-resisting alloy, while elsewhere they are of normal mild steel. All rollers are flanged in order to locate the charge and, by means of a special design arrangement, the flanged rollers may be extracted, when necessary, through the side of the furnace. Another design feature which considerably eases internal maintenance and enables any jams to be speedily released is the lift-off roof of the heating chamber, which is removable in sections. Special attention has been paid to the question of suitable bearings for the rollers, and it has been found that the most satisfactory are of the self-aligning graphite type.

Temperature control is most critical in this process,

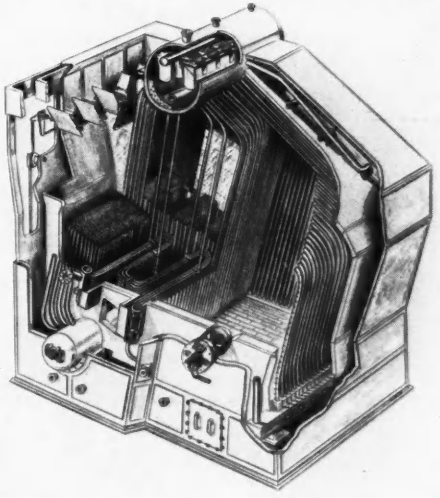


and three electronic indicating controllers are provided, one for each zone, while a 3-point recording instrument is also fitted in the control panel, so that a positive visible check on thermal conditions throughout the process cycle may be obtained. The operating temperature of the furnace varies between 325 and 650° C, depending principally upon the type of charge and the degree of anneal required.

This $1\frac{1}{2}$-ton per hour furnace is shown on the right of the illustration, while a similar type, with a capacity of 1 ton per hour, supplied to the Yorkshire Copper Works Limited in 1950, can be seen on the left.

Marine Boilers

A marine boiler combining the advantages of the twin-furnace controlled-superheat boiler with the simplicity of construction and small floor space of the integral-furnace boiler is the new " selectable-superheat" marine boiler manufactured by Babcock & Wilcox Ltd. With this boiler the steam temperature required can be selected and maintained over a wide range of load. In addition, large quantities of near-saturated steam can be provided for cargo pumping and heating, Butterworth tank cleaning, or other auxiliary services, without endangering the superheater. The selectable-superheat boiler is, at the same time, operated and fired in the same way as a normal single-furnace unit.



The general arrangement is shown in the accompanying diagram ; gas flow from the furnace is split between two parallel passes, one containing the necessary banks of convection tubes and a superheater, and one containing convection tubes only, the two sections being separated by a stud-tube water wall. Control of the relative gas flow in either of these two sections is by means of two sets of coupled dampers in the uptakes, one set being open when the other is closed. By simple damper operation the proportion of gases in the " superheater " and " saturated " passes can be varied to give the required final steam temperature. After passing the dampers, the gas streams combine to pass through an economizer and/or an air heater before being discharged through the uptakes to the funnel.

Apart from the variable steam temperature, which is a function of the damper position, control and operation of the boiler are identical with those of a standard single-pass integral-furnace boiler. The furnace can be fitted with a simple form of combustion control; this can, if necessary, be extended to operate the dampers, giving automatic control of steam temperature at any predetermined figure.

The selectable-superheat boiler, although new, is by no means untried, units having been in operation for some considerable time under the most exacting conditions. Some of its noteworthy features are :—

(1) All the advantages of a wide variation in final steam temperature (even at low loads) with a single-furnace design and a negligible increase in floor space.
(2) Straight gas flow through the convector tube banks.
(3) Positive circulation with " Cyclone " steam separators in the drum.
(4) Superheater construction of short tubes, easily handled and replaced, and provided with finger-type supports which can be replaced, when necessary, without disturbing the superheater tubes.
(5) Easy cleaning of tube banks by means of access doors on the boiler casings.
(6) Easy inspection and cleaning of the superheater, access both behind and in the centre being provided.
(7) Simple and positive control of the damper system.
(8) Dampers constructed of heat-resisting steel and positioned in the uptake from the boiler, i.e., the low gas-temperature zone, to give long life and freedom from distortion and burning.

Conveyor Development Centre

The basic conception of the new Conveyor Development Centre, recently inaugurated by the Material-Handling Division of Fisher & Ludlow Limited, of Birmingham, is quite simple, i.e., to provide a place which will house under one roof facilities for the detailed examination of material-handling problems; in short, to provide a place where the potential user of such equipment can get to grips with his problems in the company of experienced designers who have all the necessary facilities at hand to carry the discussion through to a positive conclusion.

In the demonstration area of the Centre, 17 conveyors of widely differing types, some of which are illustrated in Fig. 1, are installed. These conveyors—not models, but full-size equipment under power—total over 600 ft in length and are capable of being operated under actual working conditions. Furthermore, there is a comprehensive range of pallets, storage equipment, storage platforms, etc., comprising some 150 pallets of many different types, over 50 storage units, nearly 1000 sq ft

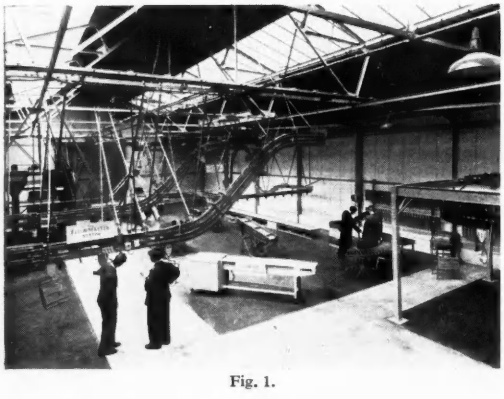


Fig. 1.

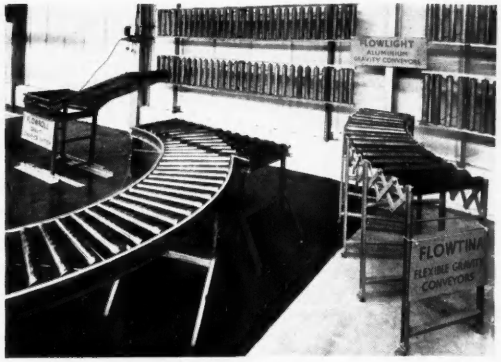


Fig. 2.

of platforming, 3250 sq ft of partitioning of five different types, and nearly 2000 ft of " Flowstrut ", used for a variety of purposes. Altogether, a very representative selection of the factory-equipment products of the Division is installed.

In addition, there is a design office, which is a complete unit with its own staff of designers and estimators, a conference room which is a permanent part of the layout, and a fitting shop where experimental work can be carried out on the spot. Finally, as a background to the Centre, there is the Fisher & Ludlow manufacturing plant—one of the largest units of its kind in Europe—where a vast range of mechanical handling equipment can be seen under production conditions.

Fig. 2 illustrates some types of " Fisholow " gravity conveyors, including (right) a concertina type of conveyor which can be bent around corners.

Tufnol Rudder Bearings for Ships

Experiments, initiated six years ago, with Tufnol for rudder bearings on coastal and ocean-going vessels of up to about 20,000 tons deadweight, have successfully demonstrated the suitability of this material for this purpose. Although the number of ships fitted with Tufnol rudder bearings over this period is now approaching one hundred, none as yet has required replacement through normal wear. In fact, the wear on the Tufnol rudder bearings in service to-date is so slight that it would appear that it will be some considerable time before the average life of Tufnol for this duty can be assessed. It is possible even at this stage, however, to make comparison with other materials.

For example, when a coastal collier of 1700 tons d.w. was recently dry-docked, the clearance between the pintles and the Tufnol rudder bearings was exactly the same as when the bearings were fitted six years ago. During this period, the collier's many sister ships have been fitted with as many as four and even five new sets of bearings made of a generally accepted material.

Worthy of mention also is an ore-carrying vessel of 7300 tons d.w., which needed a new *lignum vitae* heel pintle bearing at every dry-docking over a period of eight years until 1953, when on this occasion the bearing was found to have disappeared completely and the brass cage badly damaged. At this stage the brass cage was removed and a solid Tufnol bush fitted directly into the gudgeon. When inspected at the next dry-docking, this bush was found to be in excellent condition and showed no apparent signs of wear.

These two examples are typical of the results reported on many other ships and, as new vessels are being built, it is becoming usual for Tufnol to be specified for the rudder bearings. They are suitable for all types of rudders and can be produced as radiused strips from sheet or in tubular form from tube. The success of

Tufnol for this service is due to the unique physical properties of this synthetic laminate, giving it considerable advantages over *lignum vitae* and other materials previously used. Tufnol bearings have been used extensively for many years in rolling mills with water lubrication, so that constant immersion in sea water provides conditions in which it excels. Added to this, it resists corrosion, does not wear pintles, and is dimensionally stable. It can be stored dry indefinitely without special conditioning, so that spares can be placed in the ships' stores for long periods to await fitting at the next dry-docking.

Furthermore, sheets, strips, and tubes can be supplied by Tufnol Ltd., of Birmingham, in convenient and economical sizes and can be machined easily and accurately with the usual engineering tools.

Four-Slide Strip-Forming Machine

The use of four-slide strip-forming machines has become so widespread that Heenan & Froude Limited, of Worcester, have designed and developed a new machine, the S.207, to cater for the manufacture of components outside the range of the company's S.203A model. The S.207, which is believed to be the biggest and most powerful machine of its kind, is characterized chiefly by the fact that a very long die set can be used—some 21 in. on the standard machine and 31½ in. on the special.

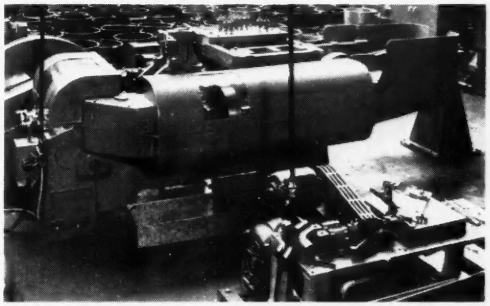
With a strip width of 2½ in., narrow forms can be made two, three, or four deep, greatly increasing the output per revolution of the cam shafts. An important point is that, though the machine appears to be very much larger than may at first sight be required for some relatively small component, it is possible to step up output greatly in excess of smaller, fast-running machines by the multiplication of parts per stroke. The standard machine incorporates an accurate mechanism for feeding and straightening the stock, plus the following alternatives :—

(1) A machine fitted with two rams, each of 15 tons capacity, a stock-shearing head, and four forming slides.
(2) A machine fitted with one ram of 15 tons capacity, a toggle-press, unit of 100 tons capacity with stock-shearing head, and four forming slides.
(3) A machine fitted with three 15-ton ram units, but without a stock-shearing head and left-hand slide.

A five-roll strip straightener is included, with adjusting rolls and guide rolls in both planes for strip entry and a quick-release mechanism. The hold on the stock is effected automatically by a positive grip, and a maximum length of 14½ in. of strip can be fed per stroke. An adjustable crank disc is provided, this being connected to the feed slide by links and levers. Provision is made for locking the crank pin when the correct length of feed has been set. The stationary grip is cam-controlled, the cam itself being easily adjustable for timing purposes.

The standard ram is of 15 tons maximum capacity and caters for strip material of 2½ in. maximum width × $\frac{3}{32}$ in. maximum thickness. The material thickness depends to a large degree, however, upon the load required to carry out the necessary press operation. The punch block and die block are kept in correct relation to each other by guide pins, thus making a complete die set which can be easily removed. The die set is 10⅜ in. long on each ram. The shearing head can be adjusted along the bed to suit the position required for the component being manufactured, and can be adapted either for a straight shear, or, within certain limits, for cutting a shaped end, according to the component.

Four forming slides are provided, the end of each slide being fitted with hardened steel rollers mounted on a needle roller assembly. The maximum strokes obtainable are :— Front slide 2¾ in., back slide 2¾ in., and side slides 4 in.; these dimensions are, however, decided after consideration of the types of components for which the machine itself will be used. Each slide is fitted with an adjustable tool block upon which the tools are mounted, and these have two-way micrometer adjustment. Wear strips are provided to take up the play between the slides and slideways.



Cams, which are adjustable for timing purposes, are manufactured in case-hardened steel and are split for easy replacement, giving a different stroke, dwell, etc. The centre tool head can be adjusted, as the centre tool itself is mounted in a slide, enabling the blank to be transferred, if required, by the action of the front tool to a position more convenient to the side slides for the forming action. The stripper is operated by levers from a positively acting cam and a certain amount of vertical forming can be carried out with this, when required. The stroke of the stripper itself is adjustable.

The machine is driven by a 7½-hp electric motor, and change gears, etc., are provided to give camshaft speeds of 40, 52, 65, and 85 rpm. A heavy flywheel is incorporated on the speed shaft.

Production Facilities for Heavy Turbines

A new heavy-turbine shop, designed for the erection and testing of the largest machines at present envisaged for power generation, i.e., up to ratings as high as 400 MW, was recently opened at the Fraser & Chalmers Engineering Works of The General Electric Co. Ltd., at Erith, Kent.

The new shop, the interior of which is shown in Fig. 1, is a steel-fabricated building, brick-filled up to 13 ft from the ground. Above this level the walls and roof are sheeted with protected metal sheeting and lined with plasterboard. The shop consists of a main bay 364 ft long and 131 ft wide, with a machine-tool annexe on one side measuring 284 ft by 40 ft. Total floor area is 59,044 sq ft. In the main bay the height to the eaves is 59 ft, and in the annexe 37 ft. The height to the apex of the roof in the main bay is 82 ft. The roof guttering has been designed to form a walkway with handrails

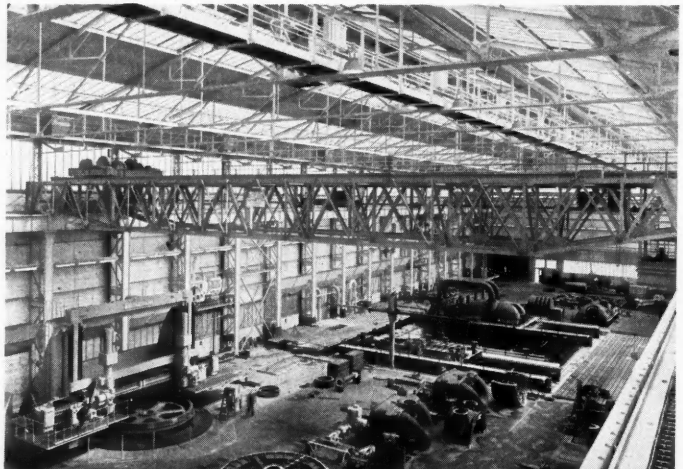


Fig. 1.

right round the building, level with the eaves. Further walkways are provided at the middle and the apex of the roof. Two 60-ton Wharton cranes with a span of 120 ft run on rails extending the full length of the shop, at a height of 43 ft. In addition, each crane has a 20-ton auxiliary hoist.

The shop is fully equipped to undertake the planing, boring, and drilling of large castings and machining of smaller parts. Rotor discs are machined in the shop, but the blades are fitted and the rotors assembled complete, and balanced, in one of the other turbine shops, whence they are delivered to the new shop for building into the machines. Most of the machine tools are housed in the annexe, but several of the larger units are accommodated in the main shop.

The pit on which turbines are erected and tested is shown diagrammatically in Fig. 2. It is 91 ft long and 87 ft across at the top. The depth of the turbine pit itself is 13 ft 1 in., and it adjoins a pit 17 ft deep for the condenser. Three machines of any of the capacities now current or planned can be erected simultaneously, the bed of the pit being designed to permit the utmost latitude in this respect, both as regards the size of the turbines and the positions of the supporting points.

The condenser was supplied by Worthington-Simpson Ltd., to deal with 45,000 lb per hr of exhaust steam from machines under test at 28 in. Hg vacuum. Lubricating oil for the turbines is circulated by motor-driven pumps through oil coolers, storage tanks, and oil-cleaning and centrifugal plant. All supply arrangements are designed to enable from one to three machines to be run simultaneously or individually at any position on the pit. To supply steam for the new shop an International Combustion boiler of special design was installed. This is a twin-furnace, oil-fired boiler which is differentially fired to provide steam at any pre-determined temperature up to 875° F. The boiler has a capacity of 45,000 lb per hr at 665 psig and is complete with its own forced- and induced-draught fans, and feed heating, including a de-aerator. All plant is equipped with E.C.G. motors and control gear. Provision has been made for an independently fired boost superheater to be provided at a later stage, in order to raise the temperature of the steam to 1060° F.

A three-phase electrical supply is brought into the switch-room from the 2850-V works ring-main circuit. Two 250-kVA external transformers step the supply down to 415 V. The low-voltage supply is brought into a six-panel board for distribution throughout the shop. A d.c. supply is obtained from the works rectifiers. A 127-kVA power-factor correction capacitor assembly is housed in the switchgear room.

In addition to a liberal provision of natural lighting from windows and continuous glazing in the roof, lighting in the main shop is derived from a combination of mercury and fluorescent sources. Natural ventilation is provided by roof cowls, and every effort has been made in planning facilities to ensure working conditions which will promote efficiency, and to enable the new shop to make a contribution worthy of the advanced standards of its technical equipment to the expanding demands for heavy electrical power plant.

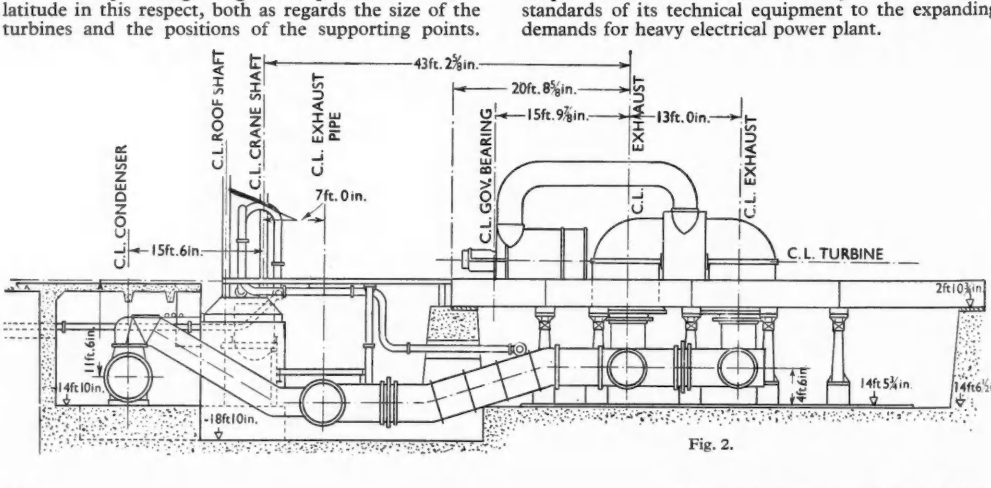


Fig. 2.

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

ELECTRIC GENERATORS AND MOTORS

The Operation of Hydrogen-Cooled Turbine Generators.

By C. C. STERRETT and R. A. TOWNE. (From *Power Apparatus and Systems* (*AIEE*), *U.S.A.*, No. 18, June 1955, pp. 433-439, 7 illustrations.)

THE proper operation of hydrogen-cooled turbine generators is necessary to assure continuity of service and to protect the large capital investment involved in generating equipment. Continuous advances in the design of generators have obliged manufacturers and operators to re-examine operating practices regularly.

In the late 1930's, hydrogen-cooled turbine generators were first put into operation. These units were generally based on load machines operated at 0·5 psig hydrogen pressure and were run in accordance with the same practices developed over the years for large air-cooled generators. Successful operation was achieved in this manner for these early, relatively small units. To meet the subsequent demand for individual units of higher ratings, manufacturers gradually increased the physical size of the generator and utilized higher hydrogen pressures. As these larger and more efficient units were placed in service, they were generally used for base-load operation. The older units were then often assigned to peak-load operation, which subjected them to more frequent load cycling. Present operating methods must be reviewed, giving careful consideration to these additional factors, thereby providing increased assurance of continuous service, long life, and minimum maintenance.

This paper is presented to stimulate discussion which will lead to a clearer understanding of the problems involved, and to the development of acceptable operating procedures. A practical method of operating hydrogen-cooled turbine generators is described, so as to satisfy present-day operating requirements. A description of the ventilation systems of hydrogen-cooled machines and a discussion of the requirements for successful operation are included. This paper applies specifically to conventionally cooled machines and not to those recently developed machines which embody coil-cooling systems wherein the coolant is brought into more direct contact with the conductors.

ELECTRICAL ENGINEERING

Mains-Voltage Stabilizers.

By R. B. STEPHENS. (From *Philips Technical Review, Holland*, Vol. 17, No. 1, July 1955, pp. 1-9, 16 illustrations.)

IT is well known that the voltage and frequency of the mains are subject to continuous fluctuations. In applications for which these fluctuations (and especially those of the voltage) are too large, matters can be improved by the use of a mains-voltage stabilizer, though the requirements to be met by such apparatus may vary considerably, according to the particular application.

After surveying the requirements which mains-voltage stabilizers should meet for various applications, this article gives a brief description of "magnetic" stabilizers and "feedback" stabilizers. The former operate on the basis of the non-linear relationship between magnetic field strength and induction in the soft-iron core of a choke. Although these stabilizers are very quick-acting, their applications are restricted by the fact that the output voltage is dependent on the mains frequency and the load power factor.

The feedback type of stabilizer, an example of which is also given, has the drawback in some applications of acting rather more slowly, owing to the fact that the voltage-sensitive element incorporated in the feedback circuit is necessarily slow-acting. This type, however, achieves a high precision and frequency independence. A new type of stabilizer is described, developed especially for an application requiring fast operation. It combines the favourable features of both the above-mentioned types, because here the output voltage of an ordinary magnetic stabilizer is kept constant with the aid of a simple feedback system. The voltage-sensitive element is a bridge circuit incorporating a thermistor. Indirect heating of the latter prevents difficulties during warming up. The influence of the ambient temperature is compensated by a second thermistor. A stability to within $\pm$ 0·5% over the temperature range of 10 to 50°C can be achieved for mains-voltage fluctuations between 180 V and 250 V, frequency variations between 47 cps and 51·5 cps, and load variations from no load to full load. The recovery time amounts to between one and two cycles of the mains frequency.

ELECTRONICS

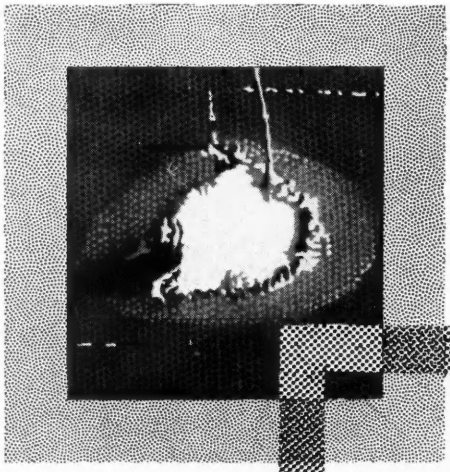
A New Method of Magnifying Electron Beam Images.

By W. R. BEAM. (From *RCA Review, U.S.A.*, Vol. 16, No. 2, June 1955, pp. 242-250, 5 illustrations.)

IN order to obtain optimum brightness and resolution in a cathode-ray-tube display, it is essential that the beam be focused to a small, sharp spot at the screen. One aspect of electron-gun development is the measurement of the size and shape of the illuminated spot produced by an unswept beam. At currents used in large kinescopes, it is impossible to stop sweeping the beam without "burning" the phosphor screen. Operation at a current low enough for safe undeflected operation usually results in a major change in spot size, owing to the change of electrode voltages and space-charge effects. An alternative is low-duty-cycle pulsed operation. When a low-current or a pulsed spot is observed through a high-power microscope, stray light, secondary electrons, and the coarseness of the phosphor all make it difficult to judge the approximate spot size. In the pulsed method, measurements are further complicated by the requirement of pulse voltages of 100 V or more; measurement of peak current at low-duty cycles also presents a problem.

This paper describes a method whereby an undistorted magnified image of the spot may be produced on a phosphor screen, magnified electronically up to forty times. A single deflection yoke sweeps the electron beam across a tiny resolving aperture at the point where the spot analysis is to be made. The current passed by the aperture forms a tiny beam, which is swept further to "paint" an enlarged image of the beam on a fluorescent screen. The method permits the use of an auxiliary photo-tube to measure spot current and current density quantitatively.

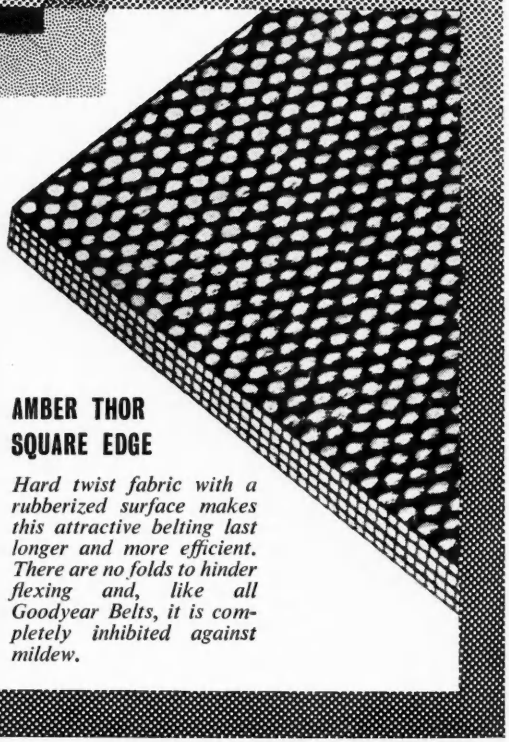
The spot-magnifying system described has proved to be a useful instrument in high-resolution electron-gun



MILDEW?

Mildew is a belt-destroyer that does its damage unseen. Often unsuspected until too late, mildew strikes beneath a belt's apparently intact cover. It can be prevented, but it cannot be cured. Mildew is a fungus and these are the conditions which allow its spores to breed and multiply: darkness, dampness, lack of ventilation, fluctuating temperatures and prolonged periods of belt idleness. Belting in store can be ruined by mildew before it has ever been used.

Mildew is a danger because some of these conditions favourable to its growth are always present. There is only one answer — to fit Goodyear because every Goodyear belt is mildew-inhibited.



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research. Electron-beam power up to 25 W can be handled without resort to pulsing schemes, and resolution depends only upon the size of the resolving aperture. The magnification system requires the most elementary equipment, and constant magnification is obtained, even with unregulated power and sweep supplies. It is not necessary to operate the tube with the cathode below ground potential, nor to use high-voltage coupling circuits. Calibration is performed with four simple measurements, two of current and two of sweep distance. Magnification may be made as large or as small as desired, in a single tube; once calibrated, it is not necessary to recalibrate unless the tube is moved.

HYDRONAMICS

Waterdrop Collisions with Solid Surfaces.

By O. G. ENGEL. (From *Journal of Research of the National Bureau of Standards, U.S.A.*, Vol. 54, No. 5, May 1955, pp. 281-298, 15 illustrations.)

EROSION by waterdrop impact has recently received attention because of the damage done to high-speed aircraft on flying through rain. The problem is not new. Similar erosion is produced in steam turbines by the waterdrops in wet steam. The destructive force causing this erosion results from the collision of the solid surface with the waterdrop. At high impact velocities a waterdrop acts as though it were a hard sphere. However, unlike a sphere of hard material, it undergoes an outward radial flow of very high velocity as a result of the collision.

The question as to the order of magnitude of the pressure developed in collisions of waterdrops against solid surfaces has been discussed since the first studies of this erosion were begun approximately 30 years ago. Efforts have been made both to calculate the pressure from theoretical considerations and to measure it experimentally.

The process of collision of one solid against another solid is well known in elasticity theory. The collision of small solids with a body of liquid has also been investigated in water-entry problems. The collision of liquid drops against a solid surface, however, has been studied very little. Some preliminary work, for the purpose of obtaining a better understanding of waterdrop-to-solid collisions, is described in this paper. This work includes a chemical mapping of the radial water flow in the impact plane; the use of high-speed motion-picture photography to "stop" the motion of the drop sufficiently during the collision, so that the stages in the transition from vertical to radial flow can be observed; and the use of Schlieren photography to study details in the radial flow.

Empirical determinations of the time dependence of the impact force and of the radial flow velocity are reported. The possible occurrence of cavitation in the radial flow is considered. A semi-empirical analysis, based upon various simplifying assumptions, leads to equations for the maximum impact pressure and for the rate of spread of the water after the collision.

IRON AND STEEL

The Passivity of Iron.

By K. F. BONHOEFFER. (From *Corrosion, U.S.A.*, Vol. 11, No. 7, July 1955, pp. 32-36, 9 illustrations.)

IF iron is immersed in nitric acid of medium concentration (S.G. about 1·2), it dissolves vigorously with evolution of gas. If, however, a high concentration (S.G. about 1·4) is chosen, a reaction certainly occurs instantaneously but is not always distinguishable by an evolution of gas and, in certain circumstances, even stops after a fraction of a second, leading the iron to a condition in which it is no longer attacked and which is designated its "passive condition." At what concentration of nitric acid this occurs depends a great deal on the type of iron, without anyone so far being able to specify the determining factors. The test temperature, the degree of agitation of the iron in the acid, and the content of nitrous acid all play a part. If the iron has become passive, the nitric acid can be strongly diluted to far below the concentrations in which the iron usually dissolves vigorously, without any perceptible attack. The passive condition thus obtained is, however, labile and can be destroyed by scratches on the metallic surface through brief contact—perhaps with ordinary iron. The restored activity can spread out over the entire piece of iron with great rapidity. On the other hand, active iron, which dissolves in nitric acid, can, in certain circumstances, be "passivated" by contact with a passive iron wire or with platinum, although this phenomenon is rarely observed. With medium acid concentrations, it can occasionally be observed that an iron activated by brief contact becomes repassivated by itself in the acid, but that a second activation of a freshly repassivated iron fails. Under similar conditions, an oscillation between the active and the passive condition is sometimes observed, in which activity and passivity places on the surface of the wire disappear. If several wires are put into such nitric acid solutions, they are mutually influenced; synchronization of the rhythms is noticed, especially if the wires are metallically connected with one another. The reciprocal influence of the iron pieces depends on the geometry of their arrangement.

In this paper, descriptions are given of the various phenomena associated with the passivation and reactivation of iron in concentrated nitric acid. Apparent and true passivation potential, apparent and true passivation current density, and passivity-producing and passivity-maintaining current density are also discussed. Information is given on equivalent current density in a redox system, the role of nitrous acid in passivation by concentrated nitric acid, the corrosion of passive iron, refractoriness toward activation, rhythms, and activity waves.

MAGNETISM

Magnetization Change and Young's Modulus in Nickel-Cobalt Alloys.

By M. YAMAMOTO and S. TANIGUCHI. (From *The Science Reports of the Research Institutes, Tôhôku University, Japan*, Series A, Vol. 7, No. 1, February 1955, pp. 35-49, 13 illustrations.)

THE generally accepted phase diagram of the nickel-cobalt system shows that, at ordinary temperatures, the face-centered cubic (γ) phase exists in the range of composition up to 70% cobalt, and the close-packed hexagonal (ε) phase in the remaining range, the mingling of these two phases occupying only a narrow range of about 2% cobalt. However, previous measurements by the authors of density, magnetic properties, and magnetostriction have indicated that the two-phase in this alloy system extends from approximately 69 to 78% cobalt, and the present investigation on Young's modulus and its magnetization change (ΔE-effect) also support this view.

Young's modulus and the ΔE-effect have been measured at ordinary temperatures by the method of magnetostrictive vibration in annealed nickel-cobalt alloys covering the entire range of composition. Young's moduli of γ-phase alloys containing less than 20% Co and of two-phase and ε-phase alloys containing 69 to 85% Co increase throughout with magnetization (the ΔE-effect of the first kind), while those of γ-phase alloys containing more than 21% Co first decrease at low magnetization and then increase (the ΔE-effect of the third kind). This negative ΔE-effect at low magnetization amounts to -5% with 50% Co, and is far more conspicuous than hitherto known. Young's moduli of ε-phase alloys containing more than 85% Co at first increase,

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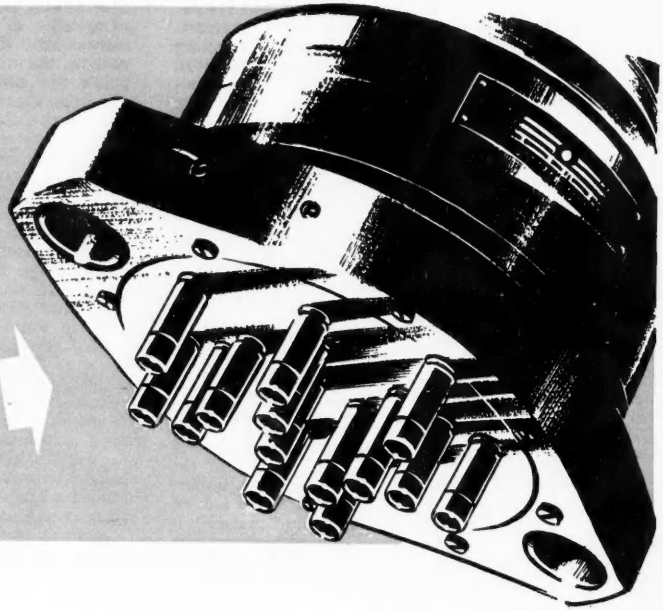

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then soon decrease, and finally increase again (the ΔE-effect of the second kind).

The saturation value of the ΔE-effect, $(\Delta E/E_0)_s$, shows two conspicuous maxima of 28·0 and 23·7% at 3 and 18% Co respectively. These values of the ΔE-effect are the highest ever found at ordinary temperatures. It is shown that the observed and computed values for $(\Delta E/E_0)_s$ are in good agreement with each other for γ-phase alloys.

Young's modulus in the unmagnetized state, E_0, takes a course nearly opposite to that of $(\Delta E/E_0)_s$ in the γ-phase region, showing two minima with 3 and 18% Co. Young's modulus in the magnetically saturated state runs parallel to E_0, taking a complicated course, even in the γ-solid-solution range.

METALLURGICAL ENGINEERING

The Effect of Temperature on the Structure and Properties of a Hardened 13% Chromium Steel.

By S. HEISKANEN. (From *Jernkontorets Annaler, Sweden*, Vol. 139, No. 6, pp. 361-411, 36 illustrations.)

THE effect of tempering on the structure and properties of a hardened 13% chromium steel has been examined and is described in this paper. In this connection an effort has been made to explain the well-known corrosion phenomenon occurring after a certain critical tempering in this type of steel. Furthermore, the tempering-time/temperature relation for maximum corrosion has been determined. Also, other phenomena connected with the carbide reactions during tempering are discussed.

A steel containing 0·18% C and 12·7% Cr was oil-hardened. The structure after this treatment consisted almost entirely of martensite, without carbides, ferrite, or retained austenite in measurable amounts. Hardened specimens were tempered at 400-550° C for different periods and subjected to hardness testing (VHN 30 kg) and corrosion testing in aqueous 5% nitric acid solution. A detailed study was made of the carbides, including their isolation, microanalysis, and investigation by X-ray diffraction and electron-microscopic methods. The influence of a tensile stress on the tempering reaction was also studied.

The results obtained and the conclusions drawn are as follows :—

(1) During tempering carbides appear in the following order: $(Fe, Cr)_3C \rightarrow (Cr, Fe)_7C_3 \rightarrow (Cr, Fe)_{23}C_6$. In the early stages of tempering the chromium content of the carbides probably corresponds to the atom ratio Cr : Fe of the untempered martensite. As the carbide transformation proceeds with continued tempering, the chromium content of the carbides increases to about 75%.

(2) Simultaneously with the concentration of chromium in the carbides, a reduction of chromium content occurs in the surrounding ferritic matrix. The low-chromium cementite is in metastable equilibrium with a very low-chromium ferrite (lower than 0·6%) at the contact surface. The low-chromium regions around the carbide particles, however, are very narrow. As the chromium percentage of the carbides increases, the chromium content of the ferrite at the contact surface also increases.

(3) The corrosion resistance of the steel examined is high in the hardened and untempered condition. Upon tempering a great number of local cells is formed, owing to the ensuing difference between the chromium content of the ferrite at the contact surfaces (carbide/ferrite) and in the rest of the ferrite. In contact with an electrolyte, e.g., during corrosion testing, the low-chromium ferrite regions function as anodes and the high-chromium ferrite regions and/or carbides as cathodes. In the early stages of tempering there are great differences in chromium content and therefore also in potential between the anodic and cathodic regions ; however, since the anodic regions are very narrow, the average corrosion for the whole test area is relatively low. At a certain stage of tempering the potential differences and the magnitude of the anodic surfaces co-operate in such a way that a very high corrosion occurs. After long tempering the potential difference has become so small that the hydrogen overvoltage on the cathodes is barely or not at all exceeded. Consequently, the local cells cannot function and the corrosion of the material again becomes relatively high.

Both the drastic corrosion and the recovery of corrosion resistance occur at the stage when the carbide $(Cr, Fe)_7C_3$ is present.

(4) The activation energy of the process, which causes the maximum corrosion structure, has been calculated to 76,400 cal/mol. This value corresponds rather well with the activation energy of chromium diffusion in ferrite.

(5) A tensile stress of 38 kg/mm² maximum during tempering did not accelerate the occurrence of maximum corrosion structure.

(6) The carbide $(Cr, Fe)_7C_3$ is formed from the previously formed cementite, and $(Cr, Fe)_{23}C_6$ likewise from $(Cr, Fe)_7C_3$ and not through precipitation within the ferrite matrix. This mechanism of chromium carbide formation seems to explain the non-appearance of a marked secondary hardening effect during the tempering of chromium steels.

WIRE AND WIRE PRODUCTS

The Influence of Nail Design and Manufacturing Practices on Joint Strength.

By A. B. DOVE. (From *Wire and Wire Products, U.S.A.*, Vol. 30, No. 6, June 1955, pp. 657-666, 724-725, 17 illustrations.)

THE common wire nail, being made from round wire, has in some measure deteriorated with improvements in wire, but the changes were not always readily visible. Improvements in dies in the early 1930's made wire smoother and cleaner and as a result the nail became smoother. Admittedly, it retained size much better than previously, but the fact that the wire and the nail were smooth tended to reduce the withdrawal value of the nail. Improved dry lubrication in wire drawing formed a slippery film, which remained on the nails and, if not removed by tumbling, further reduced the holding power of the product. Even the polishing action produced in tumbling tended to increase the smoothness, still further decreasing the resistance to withdrawal. As a result, these improvements in wire decreased the withdrawal values for nails and lowered their values as permanent fasteners.

Research conducted during the development of an improved common nail has permitted a close study of some of the factors which influence the strength of nailed timber joints. This paper shows that the factors of design which influence the holding power of timber joints are :—(*a*) The length of the nail ; (*b*) the surface area of the nail ; (*c*) the angle of helix ; (*d*) change of friction coefficients by cement coating, etching, barbing, or oxide coatings (heat treatment) ; and (*e*) the depth of threading, i.e., the difference between root and crest measurement.

It is also shown that drivability is a function of the type of point, the cross-sectional area of the nail, and the tendency to bend ; this latter can be avoided by proper design, using a $1/r$ ratio similar to column design adjusted by tensile ratio.

While, for effective usage, the most important features of the helical nail are crest angle, ratio, and measurement, it is found that, in practice, an effective crest angle may be set up for each individual nail gauge, thereby simplifying the entire design.

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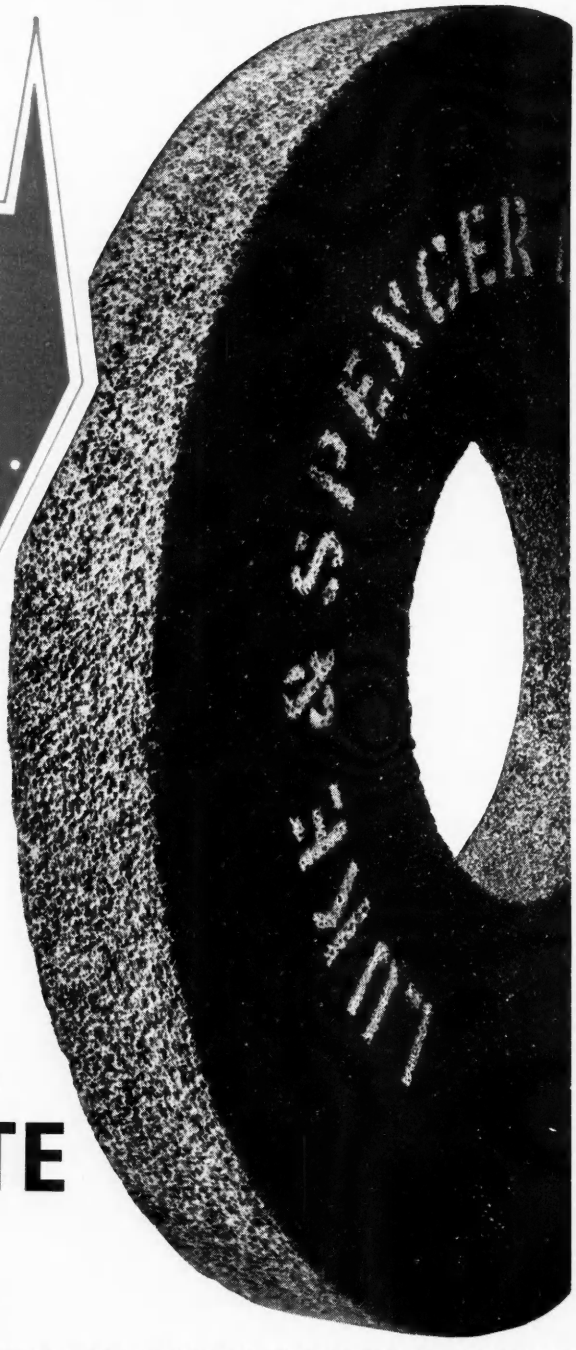

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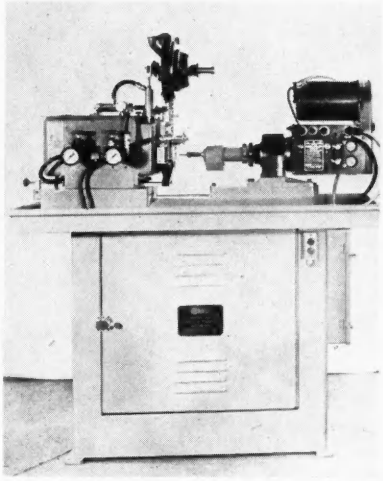
New Materials, Processes, and Equipment

AUTOMATIC DRILLING OR TAPPING MACHINE

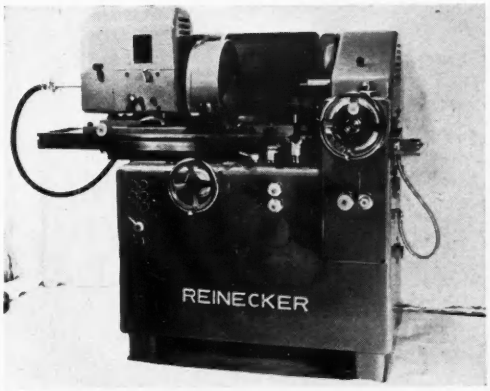
The new BECO Model 410 automatic drilling or tapping machine, manufactured by the Batchelder Engineering Co., Inc., of Springfield, Vermont, accurately locates and securely holds rivets or other headed parts for axial tapping, or drilling to very thin walls, without out-of-round distortion and central with the axis of the parts. Automatic self-reversing tapping attachments are used for tapping, and change-over from drilling to tapping is easily accomplished in about ten minutes. Coolant tanks containing different coolants are exchanged in less than two minutes, thereby eliminating the necessity for cleaning out the machine base and storing the unused coolant in other containers, when changing from drilling to tapping.



The machine operates by electrically controlled compressed air on at least 50-psi air-line pressure at approximately 500 strokes per cubic foot of free air. Solenoid 3-way valves, controlled by relays, and sensitive switches regulate the cycling. If a part is not properly positioned or if the hopper runs out of parts, the machine shuts itself off. The hoppers are not susceptible to damage in the event of an oversize or foreign part getting into them, and drill breakage due to hard spots in the work is considerably reduced. The machine is adaptable to hollow-milling, centering, step-drilling, counter-sinking, spot-facing, reaming, and certain combinations of these operations.

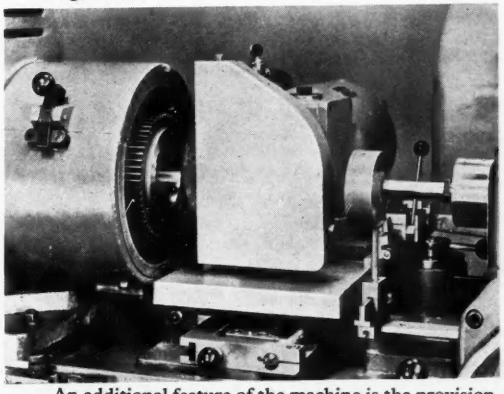
AUTOMATIC INTERNAL GRINDING MACHINE

A redesigned automatic internal grinding machine, incorporating all the latest design practice, has been introduced by J. E. Reinecker Maschinenbau GmbH, of Einsingen, Germany (British agents, Stuart Davis Ltd., of Coventry). This machine, model J.S.O.A., illustrated below, is electro-hydraulically controlled. The operating cycle is fully automatic and the indirect sizing method is used for controlling size. Plain or taper holes, straight-through, or partially blind holes can be economically ground. Rapid approach of the table, automatic starting of the work-head and coolant supply, followed by automatic switching of the table feed to



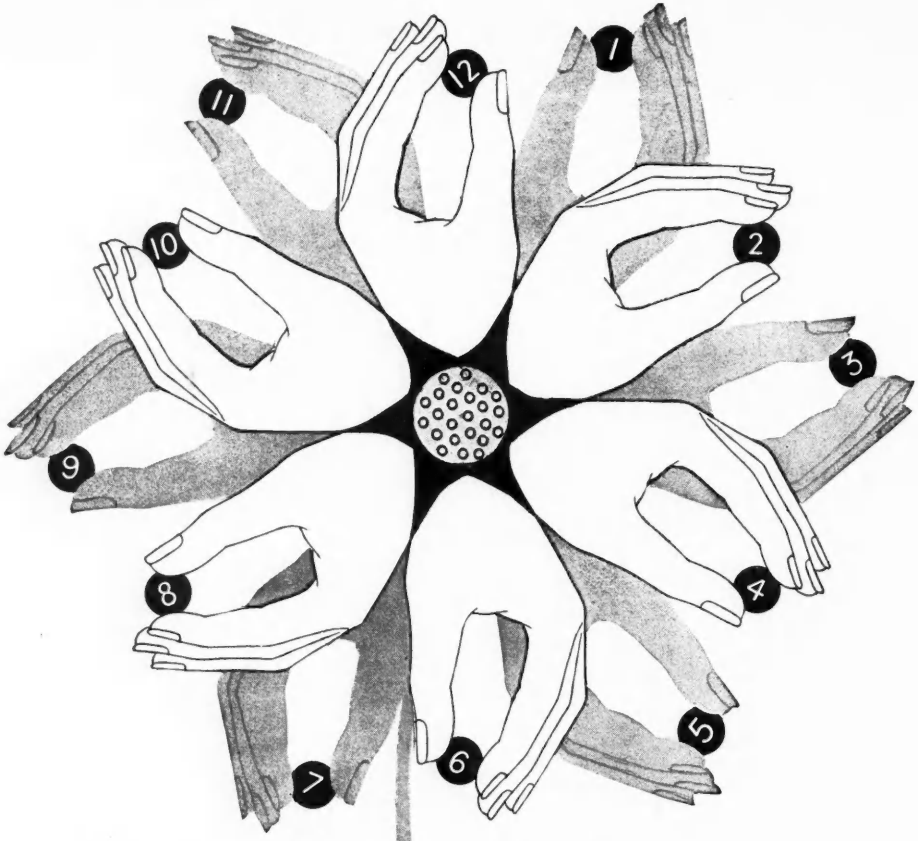
rough grinding, are accomplished by operating one starting lever.

When the bore being ground reaches the "rough" size, the table rapidly returns for automatic wheel dressing and compensation for wheel wear. Then, the table feed automatically switches to grinding speed, and grinding proceeds until the finish size is obtained. The machine then comes to a standstill after the table has rapidly returned. The coolant is switched off and the workpiece ceases to revolve. Thus, from the time of loading to unloading, the machine is completely automatic. Indirect sizing is obtained by setting the diamond dresser through a manometer adjuster. Sizing can be carried out to the finest limits. Direct sizing by using plug gauges from the rear can also be used for through-holes.



An additional feature of the machine is the provision, where required, of the face-grinding attachment illustrated above. This enables faces to be ground true to the bore. The attachment is automatically operated from the hydraulic system. Alternative units, using a cup wheel or the periphery of a plain wheel, are available.

Work is held either in a collet chuck, magnetic chuck, or three-jaw chuck. Radii or internal profiles can be ground by using special attachments. High-speed internal grinding spindles running up to 60,000 rpm, or high-frequency grinding spindles for small holes, are available. Oscillating spindles can also be supplied.



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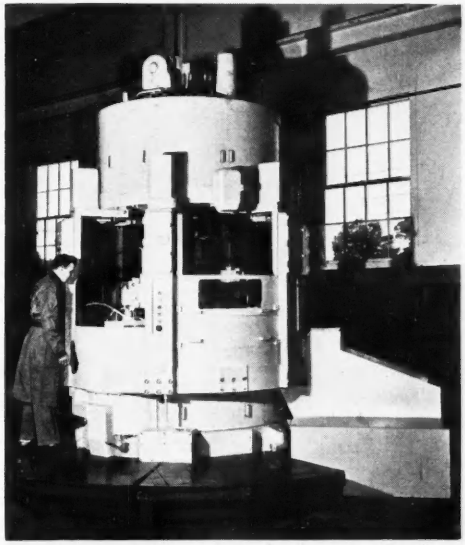
Designed for the accurate determination of the pitch of parallel screw threads at any stage of manufacture, the "Matrix" plain pitch-measuring machine announced by the Coventry Gauge & Tool Co. Ltd., of Coventry, reveals positively pitch inaccuracies of less than 0 0001 in. over 2 in. on all forms of threads and will repeat readings to 0 00002 in.

The base consists of a well-ribbed casting, accurately machined on its top surface and carrying a fixed headstock at the right-hand end, with a tailstock at the other. The headstock, besides mounting the centres, carries what is virtually the barrel of a specially constructed micrometer. The tailstock may be locked in any position, according to the length of the work. The longitudinal carriage runs on balls on hardened and ground ways and carries the specially constructed, totally enclosed micrometer nut. A weight ensures that the thrust is always in the same direction. On this, another carriage, which carries the amplifying and indicating unit (magnification × 400), is mounted, and can be traversed longitudinally and locked in any desired position. The stylus holder can be rotated to suit various set-ups. A knurled screw on the left of the stylus holder operates a spring loading device, permitting a suitable pressure between stylus and work.

The micrometer screw (40 threads per inch) has a working travel of 2 in., and any small residual pitch errors which may be present are corrected by a compensating attachment. The micrometer has been designed to take a series of specially graduated dials which can be quickly changed by means of a clamp unit and triangular spider. The dials are graduated and their application to pitches ensures rapid and accurate readings without reference to tables. A pitch-reference screw is supplied with each machine, so that its accuracy can be verified from time to time.

MULTI-SPINDLE VERTICAL CHUCKING MACHINES

A new line of multi-spindle vertical chucking machines with a new screw type of feed mechanism has been developed by the Bullard Co., of Bridgport, Conn. The most outstanding features of these machines, designated Type L "Mult-Au-Matic", are the control system, which facilitates head setting and tool adjustment with a minimum of effort on the part of the operator, and the new screw type of feed mechanism. The latter, having a total available stroke of 16 in., offers a more constant advance of the cutting tools to the work than was previously available in the cam-drum type of feed mechanism. Also, since only the required portion of the total stroke need be used, considerable saving of time in the automatic cycle can be accomplished by the new machine.



An improved type of mechanism permits faster spindle-carrier indexing, also contributing to a reduction in time lost between cuts. Selective feeds and speeds at each work station are possible through the use of a new type of gear synchronizer. For example, in the 10-in. machine, spindles may be geared to run up to 1000 rpm, as the spindles on the carrier are indexed from one station to another in an automatic cycle.

The machines are of heavy construction, permitting an input of up to 150 hp. A full line of accessories is manufactured, including multi-purpose heads, drill heads, tapping heads, and precision boring heads. Furthermore, automatic loading devices, automatic gauging equipment, and chip conveyors can be supplied.

The complete line of Type "L" machines is available in a 10-in. size, with 6, 8, 12, or 16 spindles, and 14- and 18-in. sizes, with 6 or 8 spindles. All these machines incorporate such important features as screw feed, with electrically controlled timing mechanisms for all heads; independent feeds and speeds at each working station; square lock construction, with hardened and ground ways for all saddles and slides; automatic chucking; and positive-drive synchronizers. In addition, all control units and gear units are readily accessible.

ELECTRO-PNEUMATIC CONVERTER FOR pH CONTROL

Most process-control installations in industry are operated by means of compressed air; hence, arrangements must be made to adapt electrical indicating instruments for pneumatic operation. This presents a particular problem in pH measurement and control, since the electrical signal from the pH meter may be only a few hundred microamperes; the usual practice is to amplify this by connecting the pH meter to an electronic self-balancing potentiometer which, in turn, operates the pneumatic controller. Electronic Instruments Ltd., of Richmond, Surrey, in collaboration with Foxboro-Yoxall Ltd., have now designed an electro-pneumatic converter which, for the first time, permits pneumatic pH recording and control without the interposition of the electronic potentiometer. This results in a very considerable saving in cost and enables simpler and more robust pneumatic mechanisms to be used in the instruments which follow the pH meter.

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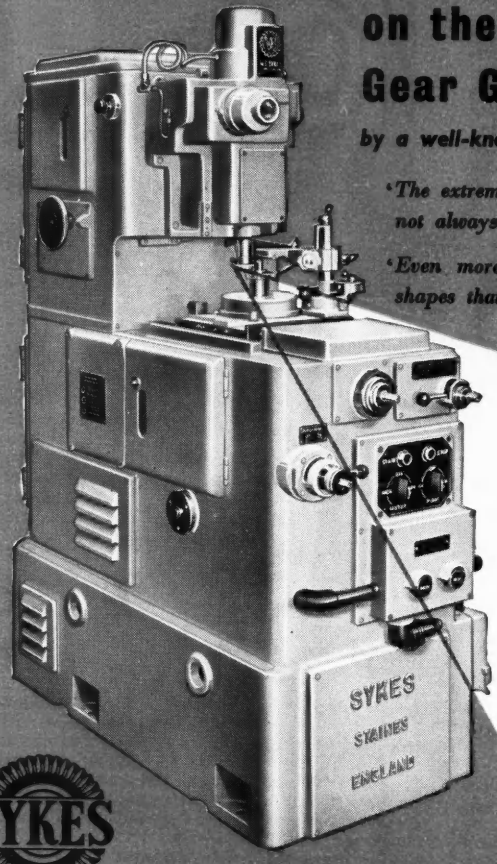
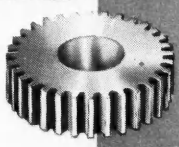
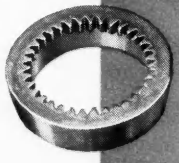


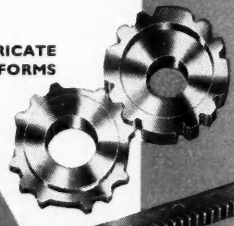
EXTERNAL HELICAL



EXTERNAL SPUR



INTERNAL SPUR & HELICAL



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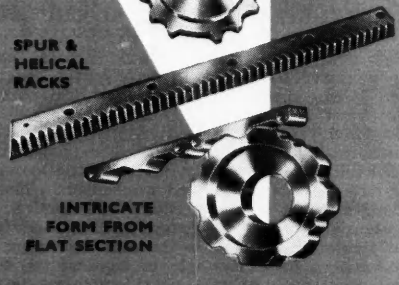

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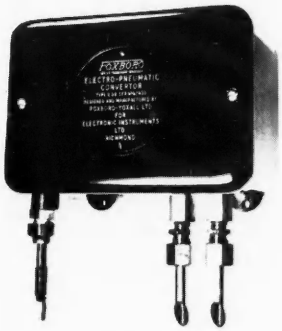
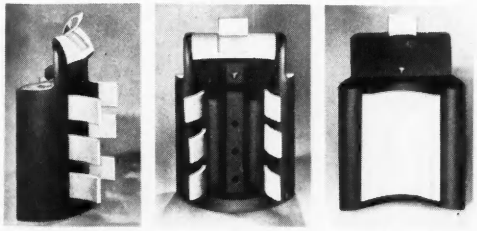


designed to be coupled to the E.I.L. Model 28A Industrial pH Meter, and the output from this instrument, which normally ranges from 0 to 14 pH, produces a corresponding air-pressure change of 3 to 15 psi. The converter consists of a small wall-mounting unit measuring approximately 8 in. × 6 in. × 5 in. Its characteristics are zero to 1400 mA for an output change of 3 to 15 psi, with an input resistance of 1500 ohms. It will operate over its full range for an input of 0 to 1 V. It can, of course, be used for other applications where a small electric current is required to operate directly into a pneumatic servo-mechanism.

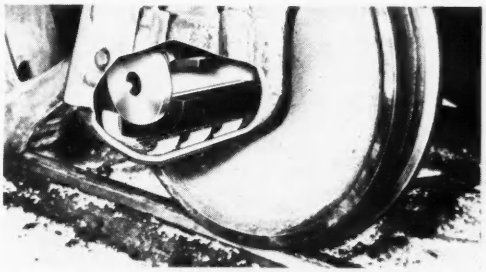
LUBRICATOR FOR RAILWAY JOURNAL BOXES

A new sponge-rubber lubricator, designed to end the ever-present problem of journal hot-boxes on railway goods trucks, has recently been developed by the U.S. Rubber Company, of New York. The lubricator, designated " Ever-Pac," forms a sealed oil reservoir at the bottom of the journal box, and pumps, squeezes, and wick-feeds filtered oil into a felt pad in constant contact with the rotating journal, providing smooth, controlled, and fully adequate journal lubrication.



A hot-box occurs when friction between the rotating journal, or axle-end, and the bearing resting on it from above becomes so great that the babbitt surface of the brass bearing is sweated out or melted. When this takes place the journal becomes cut or cracked, or may even burn out. In most cases this is caused by waste-grab—small pieces or loose ends of the waste packing drawn up under the bearing—or by waste packing settling away from the journal or rolling within the journal box. Waste-grab occurs when the packing is jarred from its normal position by train impacts, brake applications, and rough track conditions.

Easily slipped into the journal box in a few minutes, the new lubricator prevents loss of oil by leakage or splashing, without the use of costly oil seals or special types of dust guards, and without the need for welding, drilling, or machining of the journal box. Furthermore, waste-grab is eliminated because no waste packing is used ; similarly, the expensive and laborious process of waste renovation and replacement no longer arises. Oil



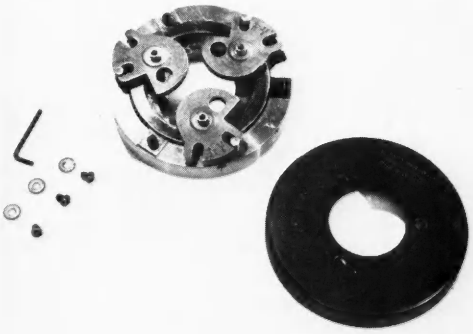
consumption is cut by more than half and original installation and replacement costs are reduced sharply.

In comparative laboratory tests journal-bearing temperatures rose 41° F between the speeds of 60 to 100 mph when cotton waste was used, but only 12° F with the synthetic sponge-rubber lubricator. At 80 and 100 mph, waste packing produced maximum bearing temperatures which were from 9 to 22° F higher than maximum bearing temperatures developed at the same speeds with the " Ever-Pac " lubricator. Tests at sub-zero temperatures showed no displacement of the lubricator and no tendency for it to " freeze down " and lose contact with the journal.

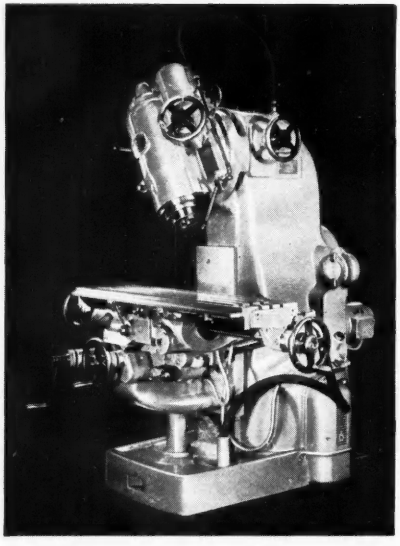
The illustrations show respectively the constructional details of the new lubricator and its actual installation in a journal box.

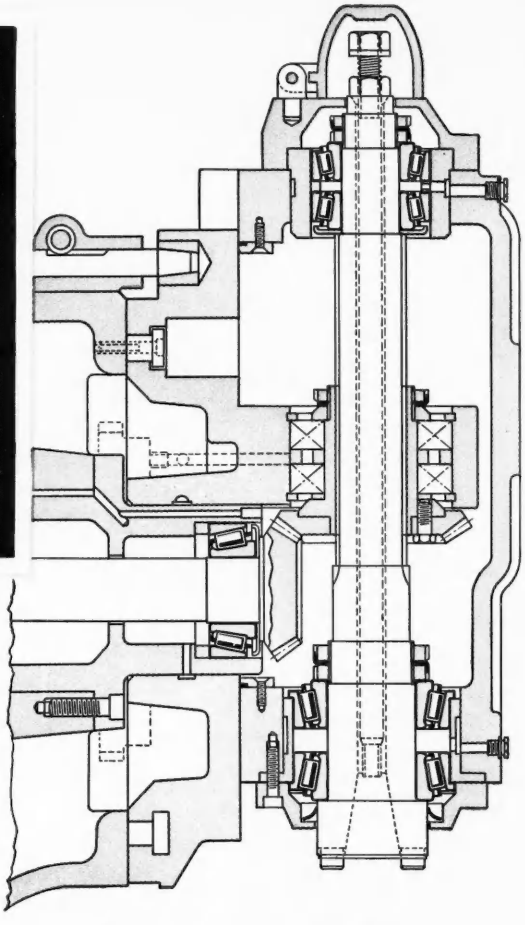
WORK DRIVER FOR LATHES

An addition to the range of work-holding devices manufactured by F. Pratt & Co. Ltd., of Halifax, is their newly introduced " Auto-Grip " work driver, the application of which to all classes of centre-lathe turnings is stated to ensure a most efficient method of driving the work and of enabling higher outputs to be achieved in all types of turning between centres. Loading and unloading is accomplished very rapidly with the simple quick-acting grip and, after the initial grip is taken, the work driver is automatically balanced, no matter how great the load applied.



New features introduced into this device include the wide gripping range which can be obtained with each set of jaws, this being due to the patent two-position indexing jaws, which enable a wider range of sizes to be gripped than was ever before possible, with the minimum number of extra sets of jaws. The fact that there are no projections, as the work driver is totally enclosed by a smooth steel cover, is a helpful safety factor, as this eliminates the risk of catching hands or clothing when the machine is started. An even drive is ensured by virtue of the special design of driving jaws, permitting a positive drive, even on eccentric and out-of-round workpieces over a wide range of sizes.





On a vertical milling machine

This interesting machine, with fixed or swivel head, has a capacity of 28 in. x 7¼ in. x 17 in. and is made by Cunliffe & Croom Ltd. of Manchester.

Among the many special features is one incorporated in the table saddle, permitting a quick run-up of the work to the cutter. Directly the work is about to be engaged by the cutter, the quick traverse is cut out and the pre-selected rate of feed goes into action: the quick traverse cannot be inadvertently re-engaged during the cut. Many other niceties of control are incorporated. The spindle is of case-hardened nickel-chrome steel and is supported on four Timken tapered-roller bearings arranged in pairs.

As will be seen in the line drawing, the pair nearest to the cutter are of the shouldered type, permitting the containing sleeve to be through-bored and turned on the outside at the same setting, thus retaining perfect concentricity. These bearings, which can be pre-loaded by the nuts on the spindle, control its endwise location, the pair at the remote end being similarly adjustable but with their cups free to float axially in their sleeve. This arrangement serves the triple purpose of taking all cutter thrust close to its origin, avoiding the effects of temperature variation on the bearing adjustment, and permitting separate adjustment of each pair of bearings.

Timken bearings are also used extensively in other parts of this machine.

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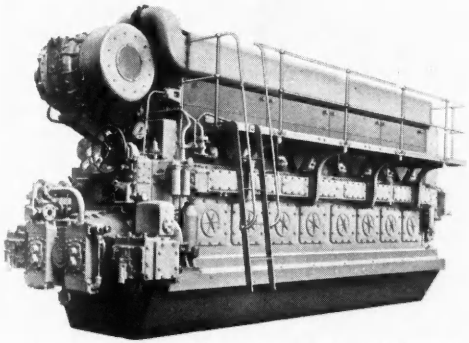
ENGINEERING, MARINE & WELDING EXHIBITION

& THE FOUNDRY TRADES' EXHIBITION

The following is a preview of some of the interesting products to be exhibited at Olympia, London, between September 1 and 15. A further selection of exhibits will be included in our next issue.

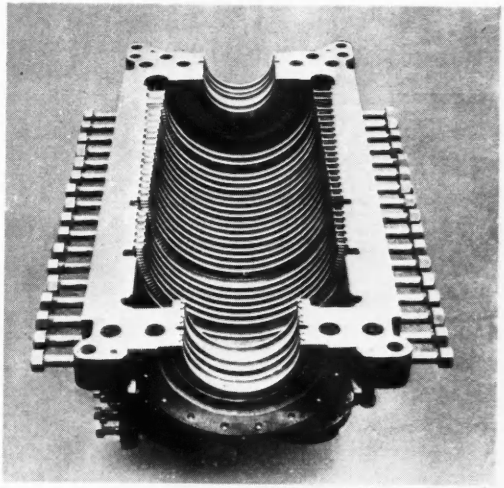
Among other equipment, **Mirrlees, Bickerton & Day Limited,** of Stockport, Cheshire, will exhibit a Mirrlees KSSDM8 marine-propulsion engine, a typical example of which is illustrated. This is a K-type 8-cylinder in-line, four-stroke, pressure-charged, direct-reversing engine with air coolers. It has a bore of 15 in. and a stroke of 18 in. with a b.m.e.p. at a rated output of 135 psi. Pressure-charging is of the Buchi type and of Brown Boveri manufacture, with an air cooler fitted. The engine is rated at 1296 bhp at 300 rpm. Air-operated reverse gear, engine-driven pressure and scavenge gear, and engine-driven fresh-water and sea-water pumps of the ram type are fitted. The K range covers 6-, 7-, and 8-cylinder vertical and 12-cylinder Vee-form engines.



Another exhibit will be the Mirrlees JS4 marine auxiliary engine, a J-type 4-cylinder in-line, four-stroke, pressure-charged engine, with a bore of 9¾ in. and a stroke of 10½ in. with b.m.e.p. at a rated output of 128 psi. Pressure-charging is of the Buchi type. This engine is rated at 368 bhp at 750 rpm. Harmonic balancing gear and engine-driven fresh-water and sea-water pumps of the centrifugal type are fitted. For trawl-winch and marine auxiliary duties the range is 3, 4, 5, 6, and 8 cylinders vertical and, additionally, 12 and 16 cylinders Vee-form for marine propulsion.

One of the main exhibits to be featured by **C. A. Parsons & Company Limited,** of Newcastle upon Tyne, will be the completely bladed high-pressure cylinder (bottom half), as illustrated, for a 60-MW, 3000 rpm, three-cylinder turbo-generator. Steam conditions are 900 psi pressure and 900° F temperature. The blading is arranged on a constant mean diameter, which enables the cylinder to be constructed with a perfectly straight and parallel flange. An interesting feature is the elimination of the vertical bolts on the horizontal joint and the fundamental change in the design of the flange. The two halves of the cylinder are held together by clamps which are applied or taken off by movement in the horizontal direction. The flanges are very narrow and deep, the upper face of the top flange and the lower face of the bottom flange being machined at a slope of 1 in 8 to the horizontal. The jaws of the clamps are machined to correspond, and the clamps are slipped on over the flanges and the horizontal studs in the two halves of the cylinder.

Another interesting exhibit will be the auxiliary shaft for a 60-MW steam turbine, which is driven from the high-pressure shaft by a worm and wormwheel. The main oil-pump wheels, one for the power oil and the other for the lubricating system, are mounted on one end of the shaft, while the speed-control governor is coupled onto the other end. Connected to the governor is the plunger which controls the pilot oil pressure to the governor valves by uncovering ports in the regulating bush, depending on the speed of the turbine, thus adjusting the opening of the governor valves.



Speed reduction gearing (3000 to 1000 rpm), used for the exciter drive on a 60-MW turbo-generator, will also be featured. The pinion is coupled to the generator rotor through a splined torsion shaft, forming a flexible quill drive. A fan is mounted on the outboard end of the pinion shaft for dealing with the ventilating air for the exciter. Oil from the turbine lubricating-oil system

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is supplied under pressure to the gear bearings and through oil sprayers to the gear teeth. Oil is also fed into the hollow pinion for lubricating the splines of the torsion shaft.

Other exhibits will include the core and windings of a 1000-kVA, 3-phase, 50-cps, 20,000/433 V, delta-star-connected, O.N.-cooled, indoor type of transformer, and a model of a 120-MVA, 3-phase, 50-cps star-connected auto-transformer, for use at the points of interconnection between the 275-kV and 132-kV systems of the Central Electricity Authority.

Two problems dealt with in the design of the industrial vacuum cleaners to be exhibited by **New Welbeck Ltd.,** of Luton, Beds., are those of noise and hygiene. By reason of their design, the powerful universal motors of these machines are almost noiseless in operation, making them ideally suited for use in hospitals and other places where the elimination of noise is of paramount importance. Clean design and the absence of a dust-bag permits the machine to be used on the production lines, in food factories, in canteens and restaurants, and wherever hygiene is essential.

The range of New Welbeck machines consists of the "Simplex," "Duplex," and "Triplex" respectively, with one, two, and three motors, for normal cleaning operations and supplied for normal lighting circuits from 22 to 250 V a.c. or d.c., and also for battery operation for use in airfields and other places where power may not be available everywhere. In addition to these machines, New Welbeck have introduced the "Bak-Vak," a light-weight version weighing only 16½ lb, which is carried on the operator's back, permitting otherwise inaccessible places, such as overhead pipes, girders, fan lights, etc., to be properly cleaned. A special 2-pole switch on the "Bak-Vak" gives the operator finger-tip control. A comprehensive set of cleaning tools and extension tubes is supplied with each machine and, in addition, special tools are available for carpet cleaning, the spraying of water, oil, cellulose, etc., together with special curved brushes for pipes, and wall brushes having a special swivel action.

The illustration shows a "Duplex" machine in operation for cleaning out the tubes of a Cochran boiler.

An extensive range of exhibits will be featured by **The English Electric Company Limited,** of London, W.C.2, covering the activities of some of their Divisions, including the Diesel Engine Division and Industrial Motor Department, the Industrial Electronics Department, and the Welding Division.

The Diesel Engine Division will be represented by a number of exhibits, including a 400-kW mobile emergency diesel generating station on wheels; an 8-cylinder, pressure-charged marine diesel engine and gearbox for installation in a cargo vessel; and a 16-cylinder Vee-form diesel engine from the English Electric SV series—as used in a variety of duties, including industrial, rail traction, and marine. The units on view will be supercharged by Napier exhaust turbo pressure-chargers.

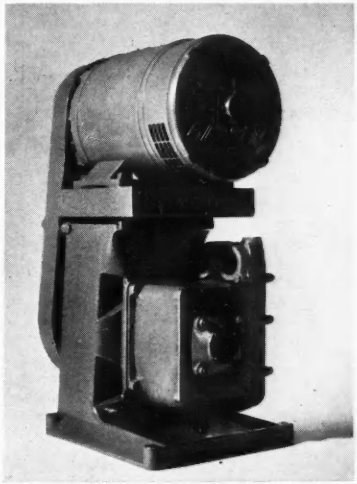
The Industrial Motor Department will show a range of British Standard dimensioned totally enclosed, fan-cooled motors, Class LY, available in preferred outputs from ½ to 25 hp. A special high-torque version of this class of motor and a newly introduced motor continuing the Class LY range up to 50 hp are now available. Also featured will be the new Class LE (protected) N.E.M.A. dimensioned motor, available in four frame diameters for horsepowers ranging from ½ to 25 hp. A sectional model of this class of motor will also be displayed. In addition, the Fantom motor, a super-silent, variable-speed machine, designed for heating and ventilating applications, will be exhibited, while a demonstration unit will illustrate the English Electric comprehensive protection system for three-phase fractional-horsepower motors.

The Industrial Electronics Department will show a 60-kW R.F. induction heater with a pin- and bush-hardening machine; a 3-hp simplified electronic controller, complete with control station and motor; and a ½-hp "Magamp" speed-controlled motor unit, complete with control station and motor.

A complete range of portable and multi-operator a.c. welding equipment will be displayed by the Welding Division. The multi-operator equipment is well known in all the heavy industries, including the shipbuilding and constructional-engineering industries. The range of portable units will include the new LWC.200 design. There will also be displayed all sizes and types of English Electric electrodes.

Two new ranges of pumps—the "K" and the "R" ranges—will be exhibited by **Megator Pumps & Compressors Ltd.,** of London, W.1. The "K" range provides a group of pumps with the main working parts in common and with capacities from 25 to 80 tons per hour. In the "R" range, an example of which, with a capacity of 16 gallons per minute, is illustrated, a new series of pumps in stainless steel and bronze, with capacities from 5 to 16 gpm, has been introduced.

Both types of pumps employ the Megator sliding-type shoe principle, and their design incorporates certain new and interesting features, including internal rubber bearings (which are water-lubricated) and radial-face



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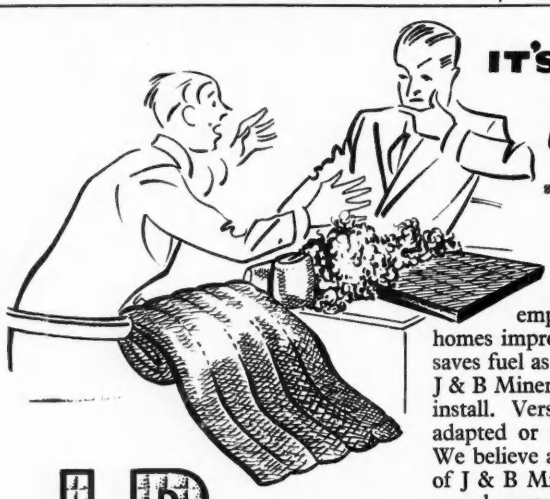

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shaft seals. In the direct-driven models special interest attaches to the drive arrangement which includes a specially designed coupling utilizing the " Metalastik " trailing-link mechanism. " R " and " K " pumps will both be shown in operation, the former handling viscous oil and the latter water.

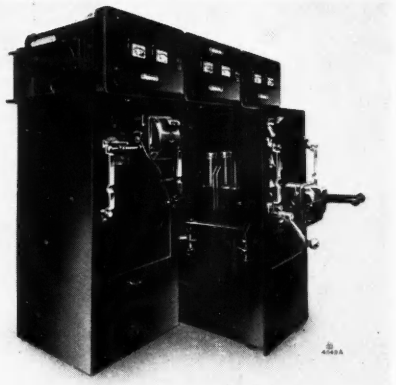
Other exhibits include the new Megator GH4 intermediate mining pump, a marine independent fire pump, and a diagrammatic layout of a Megator pressure system.

A recent addition to the range of products manufactured by **Clarke Chapman and Co. Ltd.,** of Gateshead, is their automatic chain lubricator. Among a wide variety of exhibits, a demonstration set showing this lubricator in action will be featured. Briefly, the lubricator consists of an oil-tight aluminium case enclosing the mechanism and acting as an oil bath for it. The lubricator works in conjunction with the chain sprocket wheels and is independent of chain speed.

The unit may be worked by unskilled labour and can be engaged or disengaged while the conveyor is running. Various sizes are available, according to the number of teeth in the sprocket wheel. Engagement is by a hand lever on the outside of the casing ; this slides the unit along a stub axle, engaging it with the sprocket wheel. Injector rams connected to self-centering bell-mouthed nipple connectors are then brought into action and lubricant is pumped into the chain nipples.

The nipple connectors can accommodate up to $\frac{1}{4}$ in on the pitch of the chain if it stretches or wears. A special air-jet cleaning equipment can be supplied which automatically cleans out each nipple before and after lubrication, where conditions are dusty or steam-laden.

A comprehensive display of electric switchgear, ranging from a high-tension circuit-breaker unit to limit switches and emergency push switches, will be exhibited by **George Ellison Limited,** of Birmingham. Of special interest are an 11-kV, 250 MVA circuit-breaker unit and a 660-V, 45 MVA switchboard, both of which are A.S.T.A.-tested and comply with B.S.116 : 1952. These units are simple to install and easy to maintain and keep clean. Flush-mounted instruments add to their clean appearance.



The 11-kV circuit-breaker unit (illustrated) is available for 3-phase systems. The circuit-breaker is vertically isolated and is supported on a wheeled truck, which is easily withdrawn for inspection. Incorporated are safety interlocks and arc-control devices of the cross-blast type, easily removed for contact inspection. Arrangements can be made for single or duplicate busbars, with or without selector switches. Operation can be manually-closed or power-closed by spring or d.c. solenoid. Any number of 11-kV units can be mounted together to form a switchboard, and extensions can be readily made.

The medium-voltage switchboard is made up of two 660-V circuit-breaker units. Further units can be added, as required. Housed in steel cases, they can be supplied in current-rating sizes up to 2400 A. The breakers are isolated from the busbars by horizontal withdrawal, and interlocks ensure that breakers are " off " before isolation.

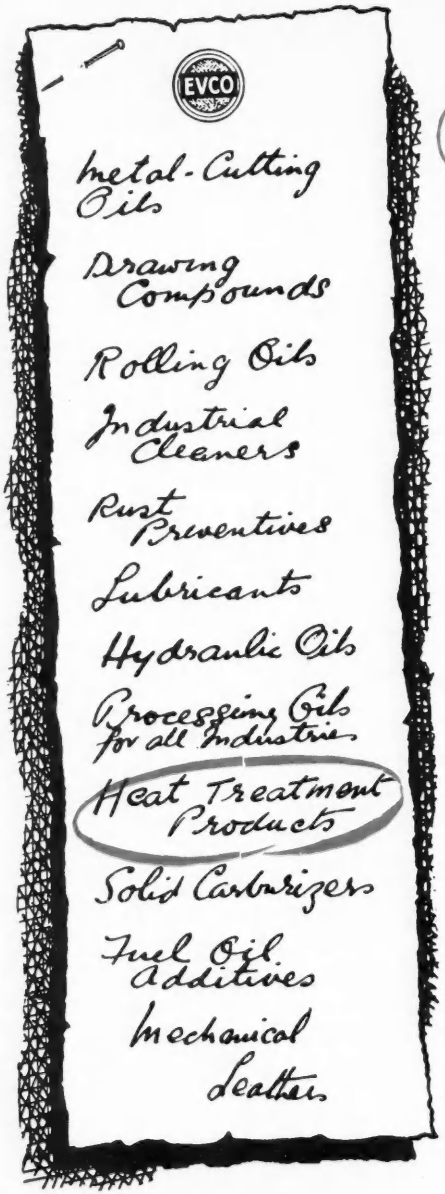
Other exhibits will include the recently introduced Ellison 20-A oil-break circuit-breaker for direct-to-line starting and for feeder circuits. The breaker is A.S.T.A.-tested and is suitable for voltages of up to 660. Incorporated is a built-in isolator available with H.R.C. fuses and auxiliary switches.

Items of equipment to be exhibited by **Broom & Wade Limited,** of High Wycombe, Bucks., will include a wide range of portable and stationary air compressors and pneumatic tools, covering the requirements of engineers and foundrymen. Among these will be examples of the new, lightweight DCL range of air compressors (an example of which, the DCL 15, is illustrated), and a new air-operated hand drill, type BWD-120, weighing $7\frac{1}{2}$ lb, suitable for rotating drills or non-rotating chisels, and especially useful for plug-holing, for foundation-bolt holes, and for chasing in brickwork, etc.

A special exhibit will be the new " Broomwade " portable rotary air compressor, delivering 600 cfm of free air at 100 psi. This unit is direct-coupled through a gear-type coupling to a 180-hp C6.SFL Rolls Royce supercharged diesel engine running at 1650 rpm.

Industrial products for which the Walterisation processes have been adopted as corrosion protection treatments will be exhibited by **The Walterisation Co. Ltd.,** of Croydon. Amongst these is the new Walterisation M.C. process, a rapid massive phosphating treatment, specially designed to suit the large-scale production techniques of industry. Walterisation M.C. is particularly suited to automatic plants of all types, and provides a heavy phosphate coating with immersion times of only 10 minutes. Also being shown is " Fasbond," a paint-bonding process which operates with remarkably low temperatures and processing times. A new development of this, " Fasbond L.W.", which gives fine paint-bonding phosphate coatings with controlled coating weights, will also be shown. These processes are suitable for spraying by the new Walterisation spray-phosphating technique.

Development of the Walterisation processes has been extended into the field of dry lubrication for wire and sheet drawing, stamping and pressing, as well as for bearings and wear resistance of moving parts. Among other processes are " Foscote," " Deran," the Walterisa-



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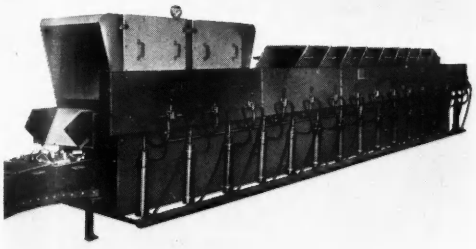


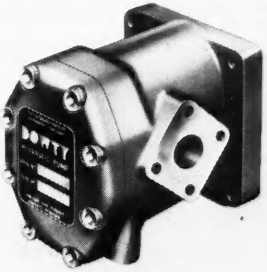
tion L. treatment for aluminium, and "Walterblak"; appropriate ancillary products are also available.

The illustration depicts an automatic tipping-basket plant suitable for use with Walterisation processes for the large-scale rustproofing of small parts.

Vee-belts, and transmission and conveyor belting, which now contain a new mildew-inhibiting agent discovered in Dunlop's research laboratories, will be exhibited by the General Rubber-Goods Division of the **Dunlop Rubber Co. Ltd.** Also on show will be rubber products for engineering, general industrial, and marine applications, including oil suction and discharge hose, sand and gravel hose, hydraulic hose, and a general range of other applicable hoses. Bearings, mechanical rubbers and mouldings, expansion joints, silicone-rubber products for flexibility at extreme temperatures, P.T.F.E. fabrications, flexible pipes, and a range of fortiflex rubber resin containers for general industrial use will also be featured.

Dunlop Special Products Ltd. will show a range of precision rubber products for engineering and marine applications, including anti-vibration mountings, flexible power-transmission couplings, inflatable seals, load-measuring capsules, and specialized all-rubber and bonded products.

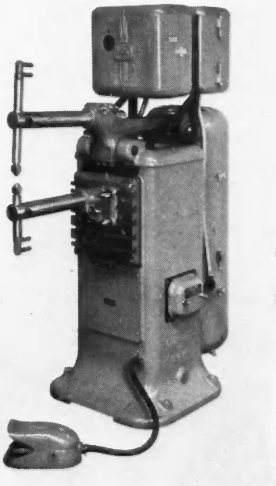
The new range of high-efficiency, gear-type pumps to be exhibited by **Dowty Hydraulic Units Ltd.,** of Cheltenham, includes four sizes of pumps, covering a wide range of output flows from 1 to 50 gallons per minute and pressure deliveries up to 2500 psi. Each pump, an example of which is illustrated, embodies a pressure-balancing system, which, in conjunction with close radial tolerances between gear teeth and bores, ensures low-loss characteristics and long life under hard working conditions.



Other exhibits will include a comprehensive range of self-sealing couplings and hydraulic rams. These rams, which are simple and robust in construction, are designed for safe remote control to fine limits and are unaffected by extremes of atmospheric temperature or by the most adverse conditions. The self-sealing couplings provide a speedy and efficient method of making completely leakproof joints and include types suitable for marine or any industrial application where the safe handling of liquids under pressure is essential.

In addition to various other units of hydraulic equipment, Dowty will also be exhibiting a range of control valves which may be employed as single units or which can be banked to form a compact multiple unit of any number of valves, using the minimum number of valves. These control valves are capable of handling pressures up to 3000 psi and are produced in three sizes, the largest having a capacity of up to 50 gpm.

Among other items of equipment to be exhibited by **Holden & Hunt Ltd.,** of Old Hill, Staffs., the 15-kVA air-operated rocker-arm spot welder illustrated will be featured. In addition, there will be shown a range of 5, 10, and 15 kVA universal pedal-operated spot-welding machines with various arm set-ups, together with a range of automatic wire butt-welding machines, with ratings between 3 and 15 kVA and capable of butt-welding from 20 swg to $\frac{1}{2}$-in. diameter in mild steel and copper.



Other exhibits will include a display of several hundred "Scadcu" electrode tips and a 15-kW twin-head rivet-heating machine, capable of heating rivets up to $\frac{3}{4}$ in. in diameter by 4 in. in length.

A wide range of their "Twinner" holding and positioning equipment will be exhibited by **Donald Ross & Partners Ltd.,** of London, N.W.1. Prominent among these exhibits will be the latest range of Twinner-Aronson universal balance positioners of varying capacities and including new free-standing models. These positioners are so designed that heavy awkward workpieces can be moved at the touch of a finger into any position for down-hand welding, as the workpiece is in balance. It is stated that these machines are also being used for marking out and inspection of castings, for polishing, metal spraying, X-ray, and many other jobs where heavy workpieces require positioning. Illustrated overleaf is a 25-cwt capacity model of this type of positioner.

The new Twinner turning rolls will also be shown. There are six models in the new range, each consisting of one power unit and one idler unit, and accommodating cylinders from 2 to 100 tons and from 12 in. to 16 ft. diameter. One of the principal features of these new turning rolls is the steel discs inserted between the

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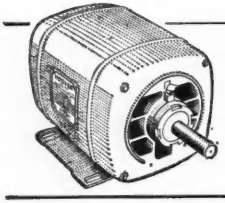

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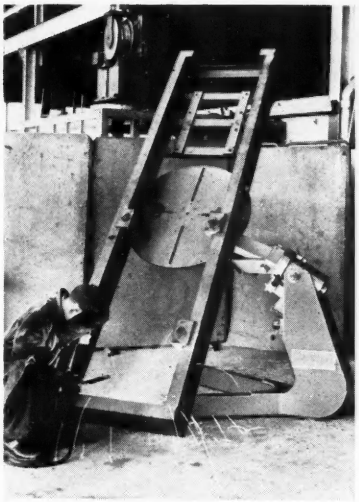


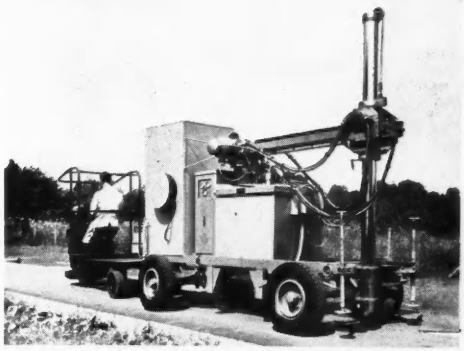
rubber rollers, to prevent overloading and crushing or wearing out of the tyres.

Exhibited for the first time will be the Twinner hydraulic platform, which enables operators to work over the centre of large drums. The platform is easily adjustable from 5 ft 2 in. to 12 ft 4 in. and has excellent forward reach. Other exhibits will include two power-driven Twinner production positioners of 5-cwt and 3-ton capacities and a comprehensive selection of holding and positioning equipment, including vices, welding slabs, pipe clamps, aligners, expanders, and a variety of magnets and clamps, all designed to speed up welding assembly.

A comprehensive range of X-ray equipment, covering all requirements, will be exhibited by **Marconi Instruments Limited,** of St. Albans, Herts. In many industries the radiographic examination of components which, though of small section or made of light materials, are not really mobile requires the use of low-powered portable equipment. In many applications mobility of the equipment is not enough. A demountable tubehead is required, which may be inserted into pipes and other hollow components or suspended for the examination of assemblies to which there is no direct access.

The equipment which fills all these requirements is the Marconi 30mA portable industrial X-ray unit, type TF 1512. Primarily suitable for the examination of plastics, fibrous materials, aluminium and magnesium and their alloys, it has a maximum rating of 85 kV peak, sufficient for radiography of small ferrous sections. The complete apparatus is readily dismantled into its essential parts, each having a handle and being easily carried by one man. The tubehead contains the X-ray tube, together with its high-tension and filament transformers, all oil-immersed in one compact assembly. The tubehead is flexibly mounted on a tube-arm with swivelling fork. The arm is supported on a self-locking, crank-operated carriage, which travels on a tubular steel column. The compact control unit is contained in a steel case with controls and meters mounted on a sloping panel and having a hand timer connected by a 6-ft lead. The control unit and column are mounted on an aluminium base with rubber-tyred castors. For many applications, only the tubehead and control unit are required. These are either mounted permanently in some position convenient for the particular job, or carried by hand to the site. Though versatile in its applications, the equipment is simple to operate and is adaptable to a wide range of supply voltages.

Another interesting exhibit will be their 250-kV constant-potential equipment, which probably provides the maximum ease of operation in the maximum number of applications. The wide kilovoltage range—from 30 to 250 kV in 2-kV steps—permits examination of components varying from plastic and aluminium items to ferrous sections up to at least three inches thick. The high-tension generator for this equipment is oil-immersed in a welded steel tank and is connected to the X-ray tube by flexible cables. The twin Greinacher circuit employed provides a smoothed, electrically stabilized output of 250,000 V at up to 15 mA. A feature of considerable importance is that this constant-potential generator enables the whole of the high-voltage energy to contribute to X-ray generation, ensuring maximum X-ray output and hence exposure times shortened by half. The screened tubehead carries an optional filter/shutter assembly with motor-driven, remotely controlled lead shutters and an automatically acknowledged, interchangeable filter. The tube, which is contained in a shock-proof, ray-proof shield, is cooled by oil, which is pumped into the hollow copper anode, whence it flows between the glass envelope and tube-shield to the return pipe. A choice of tube mounting is provided, i.e., gantry, single-column, or overhead rail suspension, while a trailer version (illustrated) is available, in which the entire equipment is mounted on a wheeled trolley, permitting the easy radiographic inspection of welds and castings, irrespective of size.



A medium-power equipment has also been designed, for use where it would be either impractical or uneconomical to employ the low and high power units. This equipment, the transportable TF 1593, basically consists of a cylindrical H.T. transformer/tube unit, which weighs less than 200 lb, and the control unit, which is of the order of 140 lb. The former contains the X-ray insert tube, the tube filament transformer, and two H.T. transformers.

Displays and continuous demonstrations of stud-welding equipment will be featured by **Crompton Parkinson Limited,** of London, W.C.2, together with exhibits exemplifying a variety of stud-welding applications—many of these being newly evolved and representative of the rapidly increasing use now being made of stud welding by practically all branches of engineering.

The demonstrations will be given with both "Nelson" and "Cyc-Arc" standard equipment, and in addition a special design of the latter, which is being increasingly employed for jig assembly mass production, will be on view. These features, therefore, should be of particular interest in that they will illustrate the adaptability of stud welding for small detail repetition production, as well as for large-scale fabrication and structural work.

The exhibits will include examples from a wide

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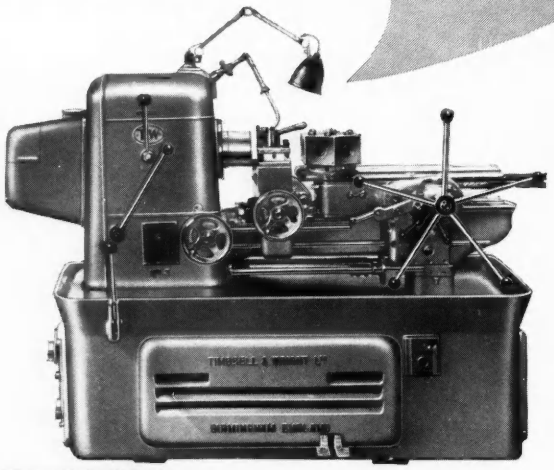

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When the next Engineering, Marine & Welding Exhibition and the Foundry Trades' Exhibition takes place at Olympia, in September, 1955, it will be 49 years since this important event was inaugurated. Since then the Exhibition has grown in size and prestige until it is now recognised by buyers of plant and equipment as the most important event in the Engineering Calendar.
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ENGINEERING, MARINE & WELDING EXHIBITION AND THE FOUNDRY TRADES' EXHIBITION

September 1st to 15th, 1955
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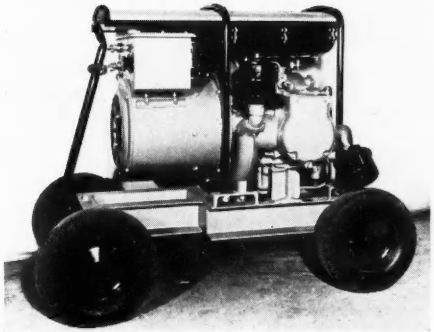
range of ferrules and studs developed for such diverse applications as the fixing of electrical components to the copper interiors of domestic appliances; the securing of hydraulic cylinder feed pipes, capable of withstanding working pressures of more than 900 psi; and the attachment of insulation and other materials to ships' steel bulkheads and aluminium superstructures. Actual examples of stud-welded components will illustrate the technical and economic advantages of stud welding.

Also to be prominently exhibited will be the "Crompark" TR/3A transformer-rectifier power source. This equipment (illustrated) was introduced only a few months ago and provides a choice of three outputs—one for stud welding up to $\frac{1}{2}$-in. diameter studs, another for single-operator arc welding with current up to 400 A, and a third for two independent arc-welding operators, using up to 200 A each. This is stated to be the first power source specifically developed for both stud welding and manual arc welding.

In addition to a new range of single-operator arc-welding machines and multi-operator equipment, and a complete range of welding electrodes, including the "Chromolac" and "Chromac" series, **Rockweld Limited,** of Croydon, will be exhibiting for the first time a new diesel-driven welding equipment of unique design. The new unit, designated "Enmac," is claimed to be the most economical unit yet produced for welding on site, average fuel consumption being less than 5 gallons for a working day of 8 to 10 hours, when using the equipment for high-duty cycle welding on site.



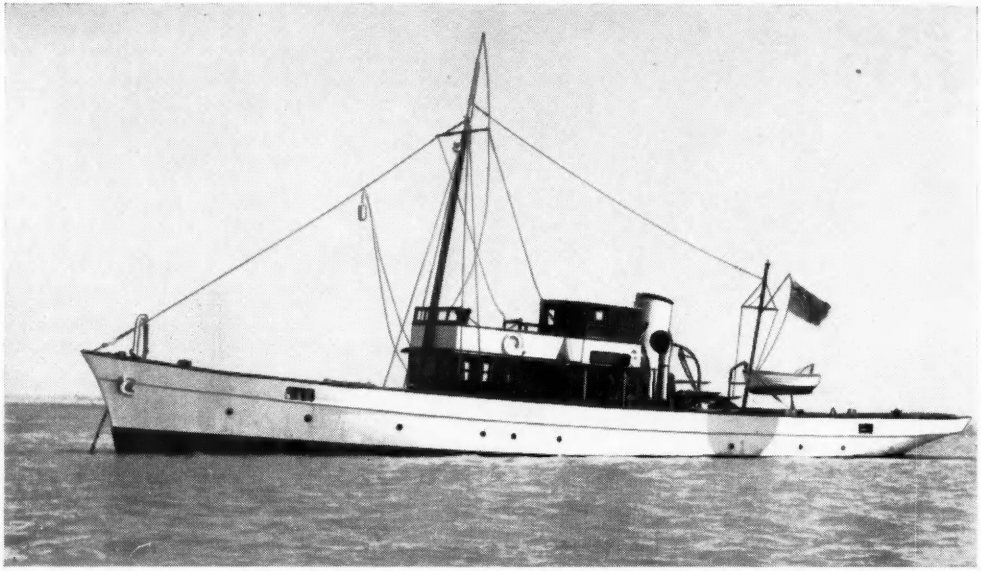
The engine is an Enfield horizontally opposed, twin-cylinder, air-cooled type, rated at 15·6 bhp at 2000 rpm, and capable of withstanding the worst possible site conditions with negligible maintenance. The generator is rated at 250 A continuous hand-welding current to BS 638, 1954. It has been possible to make a light-weight generator as a result of the intensive air-blast cooling from the substantial fan, which cools both the generator and the engine. This permits the generator to be overhung from the engine and ensures perfect alignment. The combined unit is mounted on a substantial four-wheeled trailer, as shown in the accompanying illustration.

A comprehensive range of resistance-welding machines will be displayed by **Sciaky Electric Welding Machines Limited,** of Slough, Bucks. Of these, the largest will be the Type P.A.D. 100 illustrated. This is a projection welder, nominally rated at 100 kVA, employing twin transformers and giving higher output at greater efficiency, compared with a single-transformer machine of the same rating.

Two spot welders of 150 and 25 kVA nominal rating, each having a working throat depth of 24 in., will also be shown. In the case of the smaller model, this has a capacity of welding up to two thicknesses of $\frac{1}{8}$-in. mild-steel plate, whilst the larger model is capable of fabricating light-alloy components having two equal thicknesses of 14 swg sheet, and mild-steel plate up to $\frac{3}{16}$ in. Another spot welder of the portable type will also be available for inspection. This unit is generally mounted above the work-station, the welding gun being suspended from the transformer.

In addition, a universal type of seam welder, nominally rated at 75 kVA, will be exhibited. An outstanding feature of this unit is the rapidity with which change-over from circumferential to longitudinal conditions can be achieved. The Sciaky control equipment utilized employs the latest design of dekatron timing, offering a wide range of welding times and incorporating a phase-shift heat control.

The chief item to be exhibited by **Desoutter Brothers Limited,** of Hendon, is their new pneumatic rackfeed drill. This tool is designed to simplify the drilling and reaming of $\frac{1}{2}$-in. diameter holes and over, enabling the work to be carried out by unskilled operators. Its main features include a geared hand feed, which eliminates fatigue and which enables the depth of penetration to be accurately controlled by means of an



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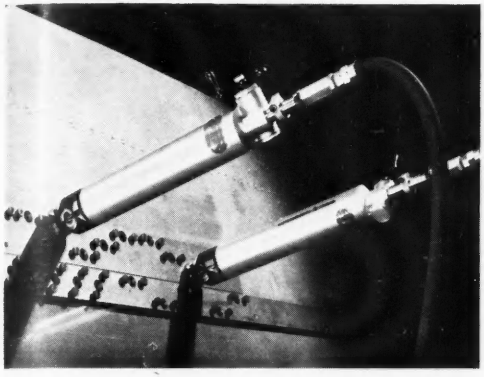


adjustable depth stop on the rack, and a bayonet-nose jig fitting which ensures correct alignment and positioning and absorbs drilling reaction.

The method of operation is as follows :—The tool is applied to the jig, and the nose is pushed home into the jig bush ; the tool is then given a quarter turn and the bayonet fitting slides under the heads of the bayonet collars. The handle is rotated, advancing the machine through a reduction-gear unit, and when the twist drill approaches the metal, the air is automatically switched on by a cam. When the hole is drilled, the handle is reversed, the machine retracts, and the motor switches off again.

The use of this rackfeed machine speeds up the drilling operation because the operator can apply a greater load with less effort, thereby using the tool to its full capacity. The pneumatic motors supplied with these drills are available in a wide range of speeds.

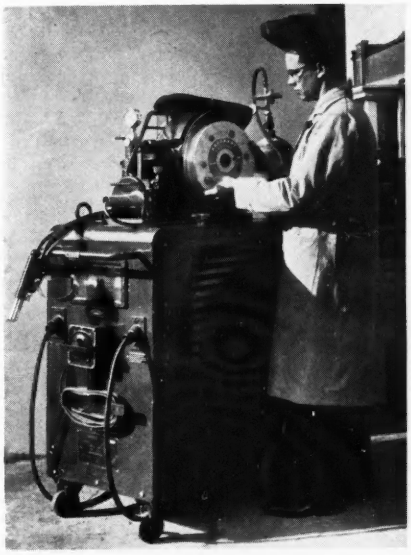
In addition to a wide range of gas-welding and cutting equipment suitable for applications for the majority of the metalworking industry, **The British Oxygen Company Limited** will be exhibiting and demonstrating for the first time an entirely new Argonaut welding machine, the Argonaut 21E, intended for welding heavier sections of light metal, bronze, stainless steel, and mild steel. This machine is a development of the existing Argonaut 3E equipment and is particularly well suited to the latest development of welding heavy carbon steels by the inert-gas-shielded method.

Other Argonarc welding equipment to be shown will include the spot-welding process and five hand-welding torches, providing a range suitable for most applications. Two of the hand-welding torches are of an entirely new design and are being shown for the first time. These are intended for welding in restricted locations and have been developed primarily for jet-engine component manufacture and similar work on complicated structures in light-gauge material.

ASEA Electric Limited, of Walthamstow, London, E.17, sole representatives in Great Britain for **Asea Svetsmaskiner AB** (**ASEASVETS**), of Stockholm, are displaying by means of cinematography, photographs, weld samples, and literature the complete ASEASVETS production range.

The weld samples will include workpieces produced by spot, seam, projection, butt, and flash welding, while the cinematographic display, which will be of special interest to visitors concerned with modern welding technique and methods, will deal with automatic arc welders, flash welding of heavy chains and short-link chains, resistance heating and upsetting machines, resistance welding of stainless-steel sinks and steel tubes, fixing pins for heat exchangers, and resistance welding of wire fabric.

A full range of pneumatic tools, including a new lightweight grinder, will be exhibited by **The Atlas Diesel Company,** of Wembley. Among the "working" exhibits will be an MLB air hoist fitted with swivelling suspension and a trolley locking device. This will be the first time that these Atlas hoist fittings, specially designed for marine use, have been shown in Britain. The locking device fitted to the air-hoist trolley for use in engine rooms prevents the trolley moving as the ship rolls. As oblique hoisting operations are essential in a ship's engine room, the Atlas MLB type of hoist is designed to operate at angles up to 30 deg.



These hoists, capable of lifting loads of five tons, have an air motor of new design fitted with cylinders arranged in star formation. All components are easily accessible for inspection and maintenance. The starting torque of the motor is independent of the air supply, ensuring full capacity, even when a small amount of air

cast for an important part . . .

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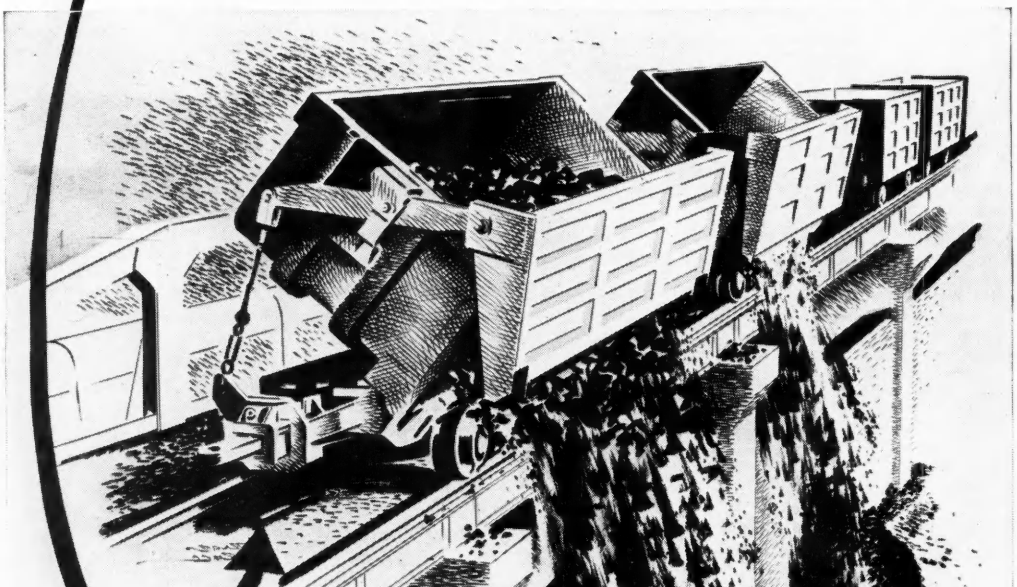
Few vehicles have to undergo more continuous shocks and vibrations than ore carrying tipper trucks. Constant shunting and loading subject them to perpetual buffeting and optimum wear. It is because of the need for calculated, unfailing strength in the frames of the Granby tippers manufactured by Robert Hudson Ltd. (illustrated), that Lloyds, with their unsurpassed facilities for scrupulous control at every stage of production are called upon to cast these vital components. These frames are cast as one complete unit for optimum strength.



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Lloyds machine as well as cast

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is turned on. This means that five adjustments of the lifting speed are possible.

Another exhibit is the Model LSS-61 sander and grinder illustrated. This pneumatic tool is designed primarily for sanding, wire brushing, and cup-wheel grinding. Two types of pad are available for sanding—a flexible rubber pad for dressing curved surfaces, and a semi-flexible disc of synthetic-resin-bonded discs supported by a cushioned backing plate. Both types are used with ⅞-in. bore discs. The semi-flexible disc is very effective when used on flat surfaces and is both superior to and more economical than the felt-backed depressed centre discs used with earlier machines. For cup-wheel grinding and wire brushing the machine is fitted with a slightly longer spindle. In common with the Atlas LSS-81, a heavier machine, the LSS-61 has a high power/weight ratio. Weighing only 6 lb, it develops nearly twice as much power as earlier models of approximately the same weight.

The main theme of the exhibits of **General Refractories Ltd.,** of Sheffield, will be the refractories requirements of the user. Products covering such requirements of all types of industrial plant will be shown, in conjunction with illuminated cross-sectional drawings of typical furnaces, indicating at a glance the recommended refractories to give the most efficient and economical service.

In addition, a comprehensive range of basic, silica, fireclay, high-alumina, and sillimanite bricks, heat- and acid-resisting materials, heat-insulating refractories, fire cements, jointing materials, and monolithic compositions, to meet every requirement, will be exhibited. Of particular interest will be a display of shell-moulding sands, with examples of their application.

Specially featured will be the Densyl silica brick, a new and outstanding development in silica refractories for use in open-hearth steel furnaces, electric furnaces, and glass furnaces. The palletization of refractories and the advantages this service offers to users, including freedom from damage in transport and economy in stacking, will also be demonstrated.

Several examples from their range of foundry plant will be exhibited by **Polford Engineering Co. Ltd.,** of Newcastle-upon-Tyne, including a new type of gas-fired mould drier with several improved features. This drier incorporates a flame-failure device and special connections for horizontal and vertical operation. It consumes up to 900 cu ft of gas at 1½ in. w.g. per hour, and will dry a mould of over 200 cu ft in 5 hours.

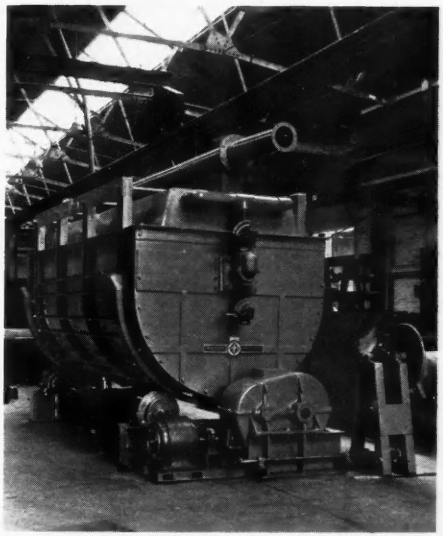
Another recent development is a portable rotary feeder hopper for feeding sand, coal-dust, etc. at predetermined rates. It is so designed that the material being fed cannot adhere to the sides. In addition, there will be a combined magnetic separator and vibratory screen, with a screen cloth of 120-ton tensile wire and a powerful magnetic pulley of the "permanent" type, which is nearly 100% effective in the reclamation of scrap metal.

A core-sand mixer to be exhibited will deal with all types of compound, including semi-solids. All working parts are well protected against sand. The drive is by means of a totally enclosed motor through a worm gear, and the guard is interlocked electrically, so that, when it is lifted, the motor is switched off.

A central-axis oil-fired melting furnace has hand-operated tilting gear. The model to be shown is arranged for oil firing with an efficient burner and air supply from an electrically driven fan. Alternatively, the furnace can be supplied for coke or gas firing. A special "preheater" top is incorporated and a drop-bottom permits quick release of metal in the event of the pot bursting.

The exhibits will be completed by a vibratory shake-out of robust design, a foundry ladle, and a display of foundry requisites and protective clothing.

Among other items of equipment, the **Monometer Manufacturing Co. Ltd.,** of London, W.C.2, will be exhibiting a 12-ton (iron) capacity fully mechanized hot-metal receiver (illustrated), for holding irons at pouring temperatures, as tapped from the cupola, for long or short periods, thereby ensuring a supply of hot metal at all times.



Other items will include a 2-ton capacity fully mechanized oil-fired rotary melting furnace for iron and steel and for all non-ferrous metals, including copper, gunmetal, and aluminium; an oil- or gas-fired semi-rotary furnace for copper, gunmetal, and aluminium, of ½-ton capacity; and a double-ram hydraulic lip-axis oil- or gas-fired crucible tilting furnace for all non-ferrous metals.

Two new "Radyne" induction heaters will be exhibited by **Radio Heaters Ltd.,** of Wokingham, Berks. Of these, the smaller is the first bench-type induction heater to be available in Great Britain, and is stated to be the only bench-type unit with fully variable power-output matching in the world. This new equipment, which is only 2 ft 7 in. in length and 1 ft 10 in. back to front, is ideal for all smaller soldering and brazing work. It is housed in an extremely robust cast-aluminium case, which is built to withstand workshop conditions for a lifetime. A special high-impedance version with a water-recirculator trolley is available for electronic and other work where a flexible output lead is required. The output of this unit is 3 kW.

The second new "Radyne" equipment to be displayed is a completely self-contained 25-kW output unit, stated to be the only equipment of its capacity in the world available with a completely self-contained water-cooling system. The floor area occupied by this unit is only 4 ft. wide by 3 ft deep. The equipment has a fully variable power-output matching control and is available with all the usual accessories.

Also on display will be a 6-kW soldering and brazing induction heater, together with a 6-kW induction melting unit. This small unit is capable of melting 5 lb of steel in 35 minutes. In addition to the range of induction heaters on display, there will be shown a compact water recirculator, capable of dissipating up to 20 kW. This unit is ideal for the cooling of spot welders and other equipment, in addition to induction heaters, radio transmitters, etc.

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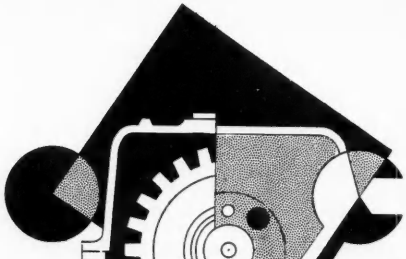

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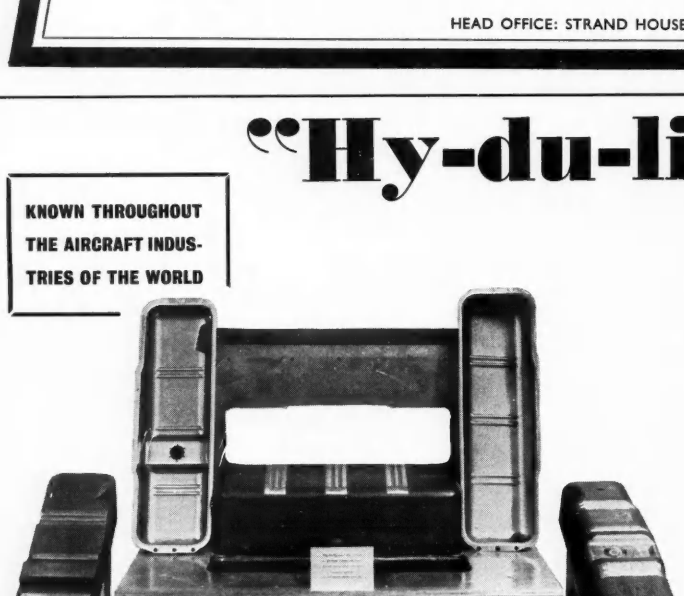

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Illustration shows "Hy-du-lignum" Press Tool, used on DH 600 Clearing, Treble Action Press for 20 gauge mild steel Petrol Tank Body Pressings. Interchangeable Punches and Ejectors with common die and pressure plates to produce top and bottom body halves, 3ft. long × 10in. wide × 8in. deep. Photograph by Courtesy of Morris Motors (Radiators) Limited.

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NEWS OF THE MONTH

PERSONAL

Mr. Robert S. J. Ansell, who has previously held appointments with the Lapointe Machine Tool Co. Ltd. and the De Havilland Aircraft Co. Ltd., has been appointed sales manager of the Broach Division of B.S.A. Tools Ltd., Redditch.

Major C. J. P. Ball, D.S.O., M.C., chairman and managing director of Magnesium Elektron Ltd., has relinquished the latter position in favour of **Dr. C. J. Smithells, M.C.,** but remains chairman of the company. **Brig. A. G. Cole, O.B.E.,** assistant managing director, has been appointed commercial director. **Dr. S. J. Fletcher** remains technical director.

Mr. A. D. Busby, B.Sc., A.I.M., has resigned his appointment with The Mond Nickel Co. Ltd. and will take up the position of deputy process development manager of the Titanium Department of I.C.I. (Metals) Ltd., Witton, Birmingham.

Mr. W. A. Clarke has been appointed production development manager of the Dunlop Rubber Co. Ltd.'s factory at Hanau, Germany.

Mr. J. Clement, B.Sc., M.I.E.E., has been appointed assistant manager, home sales, at the head office of the British Thomson-Houston Co. Ltd., Rugby.

Dr. R. Cockburn, C.B., O.B.E., has been appointed Deputy Controller of Electronics, Ministry of Supply, in succession to **Rear-Admiral G. Burghard, C.B., D.S.O. (retd.).**

Mr. Frank Cowloshaw, A.I.M., has been appointed to take charge of the new factory laboratory of The Dart Spring Co. Ltd., West Bromwich.

Mr. P. D. Crowther, M.Sc., A.I.M., has been elected a director of Peglers Ltd., Belmont Works, Doncaster.

Mr. John R. Davies has been appointed Midland area manager of Newall Group Sales Ltd. and will operate, for the time being, from his home address at Simonsmede, Green Hill, Evesham, Worcs.

Mr. G. A. Dickins, B.Sc., F.Inst.P., has been appointed assistant manager of the technical department of the Vacuum Oil Co. Ltd., Caxton House, London, S.W.1. **Mr. V. H. Rumble, B.Sc.,** has been appointed to succeed Mr. Dickins as superintendent of the Wandsworth Central Laboratories of the company and will also continue in charge of the Products Division. **Mr. F. J. Patman** and **Mr. P. E. B. Vaile** have been appointed assistant supervisors of the Products Division. **Mr. T. Paterson** has been transferred to Headquarters with responsibility for patents and industrial hazards.

Mr. George H. Dowty, chairman of Dowty Equipment Ltd., Cheltenham, has been appointed a director of Remploy Ltd.

Mr. H. Dunlop and **Mr. C. E. H. Eckersley, M.I.Mech.E., M.Inst.F.,** have been elected to the Board of Davidson & Co. Ltd., Sirocco Engineering Works, Belfast.

Mr. A. G. Elliott has been appointed works engineer of the Sheepbridge Engineering Group, Chesterfield. **Mr. A. Wells** has been appointed production controller of Sheepbridge Equipment Ltd. **Mr. E. Dennis** has been appointed sales manager of Automotive Engineering Ltd., Twickenham, and of Light Production Ltd., Slough.

The Rt. Hon. the Viscount Falmouth has been re-elected president and **Sir Harold Roxbee Cox, Dr. S. F. Dorey,** chief engineer surveyor of Lloyd's Register of Shipping, and **Vice-Admiral Sir Frank Mason,** engineer-in-chief of the Fleet, have been re-elected vice-presidents of The British Internal Combustion Engine Research Association. **Brigadier H. P. Drayson,** director of Royal Engineer Equipment, Ministry of Supply, has been elected a vice-president. **Mr. V. H. Hopkins** and **Mr. A. C. Yeates** have been elected to the Council, to whose chairman **Mr. J. Calderwood** has been elected.

Mr. G. W. H. Gardner, C.B., C.B.E., Director General of Technical Development (Air) in the Ministry of Supply, has been appointed Director of the Royal Aircraft Establishment, Farnborough, with effect from 1st November, in succession to **Sir Arnold Hall, F.R.S.,** who resigned to accept an industrial appointment.

Mr. B. B. Green, M.C. and **Mr. W. J. McBride, A.M.I.Mech.E.,** have been elected to the Board of Edgar Allen & Co. Ltd., Imperial Steel Works, Sheffield 9. Mr. Green will act, in addition to serving as a director, as assistant to Mr. H. D. Boyd, general sales manager of the company. Mr. McBride remains general manager of the Engineering Department and a director of the British Rema Manufacturing Co. Ltd.

Mr. F. A. C. Guepin has been elected chairman and Mr. W. F. Mitchell vice-chairman of the Shell Chemical Co. Ltd., formed by the Shell Petroleum Co. Ltd. to take over the activities of Shell Chemical Manufacturing Co. Ltd. and Shell Chemicals Ltd. **Mr. L. H. Williams** has been appointed managing director, **Mr. G. H. W. Cullinan** commercial director and deputy managing director, and **Mr. E. Le Q. Herbert** executive director of manufacturing of the new company.

Mr. Richard Hodgson has been elected vice-president and has been promoted to the position of general manager of the Reconnaissance Systems Division of Fairchild Camera and Instrument Corporation, Robbins Lane, Syosset, L.I., New York.

Mr. D. C. Johnson, M.A.(Cantab.), has been appointed Professor of Mechanical Engineering at the University of Leeds as from January, 1956.

Mr. John A. Jost has joined the Kewanee-Ross Corporation (Ross Heater Division), Buffalo, N.Y., as heat exchanger development engineer.

Mr. D. E. Lambert, B.Sc.(Eng.), M.I.E.E., M.A.I.E.E., has been appointed manager of the Switchgear Division of Brush Electrical Engineering Co. Ltd., Loughborough, as from October 1st.

Mr. G. M. McIlwrick, B.Sc., A.R.T.C., A.M.I.Mech. E., A.M.I.E.E., has been appointed consulting engineer to the British Thomson-Houston Co. Ltd., Rugby, in succession to **Mr. C. A. Mertin, M.I.E.E.,** who has retired after 36 years of service with the company.

Dr. Donald Parkinson, F.I.R.I., F.Inst.P., F.G.S., manager of the Dunlop Research Centre, Birmingham, is retiring at the end of this month.

Dr. E. A. Perren has been appointed chief superintendent of the Chemical Defence Experimental Establishment, Porton, in succession to **Mr. S. A. Mumford.**

Mr. J. W. Platt has been elected chairman and **Mr. E. Le Q. Herbert** has been appointed managing director of the Shell Refining and Marketing Co. Ltd.

Mr. L. W. H. Rea, general manager of Edwin Danks & Co. (Oldbury) Ltd., has been appointed managing director of the company, in succession to **Mr. J. Smith, M.I.Mech.E.,** who has been elected chairman of the company.

Mr. Elwood H. Rogge, assistant production manager of Leeds & Northrup Company, has been appointed local manager of the firm's new plant at North Wales, Pa.

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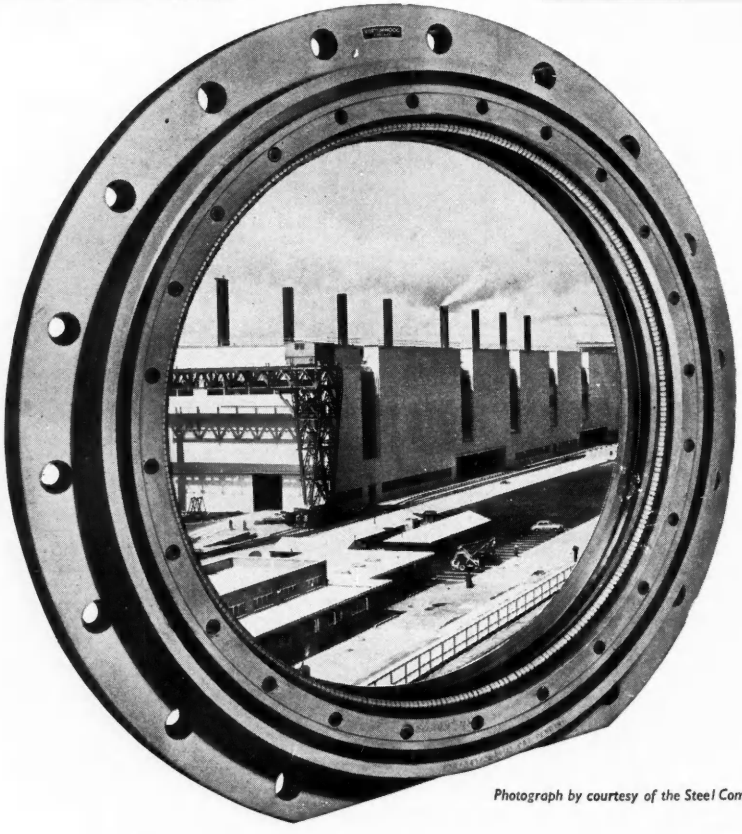

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Dr. Warren C. Stoker, Head of the Computer Laboratory at Rensselaer Polytechnic Institute, has been appointed director of the new R.P.I. Hartford Graduate Center, Hartford, Conn., U.S.A.

Mr. W. R. Storey, M.B.E., M.I.Mech.E., managing director of the Salt Division of I.C.I. Ltd. until his recent retirement, has joined the Graviner Manufacturing Co. Ltd., 1/2 Babmaes Street, London, S.W.1, as technical adviser on industrial explosion suppression and protection.

Mr. Ernest F. Thompson, works manager of the Dowlais, South Wales factory of the B.S.A. Co. Ltd., has been appointed works manager of the Redditch works, including the B.S.A. precision casting foundry.

Col. H. T. Thornley, managing director of J. and H. McLaren Ltd., Leeds, has been appointed director of administration and supply of The Brush Group Ltd. He will be directly responsible to **Mr. Miles Beevor,** managing director of The Brush Group.

Mr. Arthur Townhill, M.A.S.A.E., M.A.I.M.E., of 739 Alma Real, Pacific Palisades, California, has joined the Harwill Corporation, Los Angeles, as director of engineering.

Mr. M. J. Tustin has been elected to the Board and has been appointed director and general manager of The Standard Motor Co. Ltd., Canley, Coventry.

Mr. C. J. Underwood has been appointed export sales manager of Consolidated Engineering Corporation, 300 North Sierra Madre Villa, Pasadena 15, California, in control of the company's sales organization for data-processing, analytical and control instruments in 19 countries.

Mr. J. Watkins, B.Sc., A.F.R.Ae.S., A.M.A.S.M.E., has been appointed senior aerodynamicist of the Solar Aircraft Company, San Diego, California.

Mr. L. E. Watts has been appointed works manager of the Millar's Machinery Co. Ltd., Bishop's Stortford works.

MR. GEORGE ELLISON

It is with deep regret that we announce the death of Mr. George Ellison in his 83rd year at Rheinfelden in Switzerland.

Mr. Ellison was chairman of the switchgear works of George Ellison Ltd., of Tufnol Ltd. and of Alfred Ellison Ltd.

He was educated at Manchester Grammar School and, after serving an apprenticeship with the Oerlikon Company in Switzerland, he studied at the University of Winterthur.

In 1893 he went to America and worked with the Westinghouse Company as designer and chief draughtsman and also with the Western Electric Co. in Pittsburgh, New York and Chicago. Returning to Europe in 1898, he started business in Paris to make and sell electric switchgear.

The business in Paris grew rapidly and Mr. Ellison was not undeservedly styled "The father of the French Switchgear Industry."

In 1906 the business was transferred to Birmingham. It quickly outgrew its accommodation and in 1916 the original buildings of the present factory were built at Perry Barr.

In 1929 Mr. Ellison founded Tufnol Ltd. under its former name of Ellison Insulations Ltd. and in 1946 the foundry of Alfred Ellison Ltd. was brought into the Ellison Group of Companies.

Mr. Ellison took a lifelong interest in Industrial Welfare. He was a Life Governor of the University of Birmingham and a benefactor to the Queen Elizabeth Hospital, Birmingham.

The interment took place at Interlaken on July 20, 1955.

MR. F. G. PENNY

With deep regret we announce the sudden death at Derby, on August 6, after a short illness, of Mr. F. G. Penny, M.I.C.E., M.I.Mech.E., managing director of International Combustion (Holdings) Ltd., chairman of Aberdare Cables (Holdings) Ltd., and a director of many other companies.

MR. ROLAND H. HUDSON

We announce with great regret the sudden death of Mr. Roland H. Hudson, London Manager of John Holroyd & Co. Ltd., Milnrow, Lancashire, who died on the 17th July whilst on holiday in Majorca.

MR. GEORGE OLDHAM

We announce with deep regret the death of Mr. George Oldham, joint managing director of Oldham & Son Ltd., Denton, Manchester, who died on Monday, August 1st, in the Royal Infirmary, Manchester, following a severe heart attack.

A grandson of the founder of the firm, Mr. Oldham was 68 years of age. As a young engineer he specialized in the company's mining activities and was intimately connected with the production of the Oldham miners' electric lamp.

BUSINESS NOTES

The Brightside Foundry and Engineering Co. Ltd., Sheffield, have formed the Brightside Heating & Engineering Co. Ltd. as a wholly-owned subsidiary company, to take over the firm's heating, air-treatment and pipe-work activities. Mr. Ambrose Firth has been elected chairman and Mr. T. C. Firth, Mr. W. S. Richards and Mr. W. B. James, directors of the new company.

W. Fearnhough Ltd., Garden Street Works, Sheffield 1, have opened a new branch at 2/10 Trundleys Road, London S.E.8, where also a re-grinding service has been established.

The Telegraph Construction and Maintenance Co. Ltd. has established a new Metals Group which embraces their new factory and Sankey-Telcon Ltd. at Crawley; Telcon-Magnetic Cores Ltd., Chapelhall, Lanarkshire; Temco Ltd., Lydbrook, Gloucestershire; and the recently acquired Magnetic and Electrical Alloys Ltd., Burnbank, Hamilton. Mr. W. F. Randall has been appointed managing director of the Group.

Edwards High Vacuum Ltd., Crawley, has formed in conjunction with the Societa Apparecchi Elettrici e Scientifici a subsidiary company, Edwards Alto Vuoto S.p.A., with offices in Milan.

Leyland Motors Ltd. has formed a new company, Ashok Leylands Ltd., for the manufacture of engines and vehicles in India. Sir A. Ramaswami Mudaliar is the chairman of the company.

W. G. Bagnall Ltd., Stafford, has concluded an agreement with Morrison & Bearby Ltd., Newcastle, N.S.W., Australia, for the manufacture of diesel shunting locomotives to Bagnall design.

Dunford and Elliott (Sheffield) Ltd. has formed a subsidiary company, Dunford and Elliott Process Engineering Ltd., which will operate at Linford Street, London S.W.8.

The Sheffield Twist Drill and Steel Co. Ltd., Sheffield has acquired the whole issued share capital of Accurate Screw Threads Ltd., Hednesford, Staffs. Mr. H. Morris continues as managing director of the latter company, and Mr. W. T. Brooks has been appointed production manager.

The Coniston Co. Ltd., Eagle House, High Street, London S.W.19, has been formed for carrying out the design of heavy projects and process plants. Mr. L. J. Schwartz is chairman and managing director of the company.

Canada Wire and Cable Co., the General Cable Corporation, and the Telegraph Construction and Maintenance Co. Ltd. have formed a new company, Telecables and Wires Ltd., Fort Garry, Winnipeg, Canada, where a telephone wire and cable-making plant will be erected.

Igranic Electric Co. Ltd. announce that Alan Colless Pty. Ltd. have appointed Clark-Strickland Pty. Ltd., 17 McKillop Street, Melbourne, C.1, Australia, to act as their agents for Igranic motor control gear throughout the State of Victoria.

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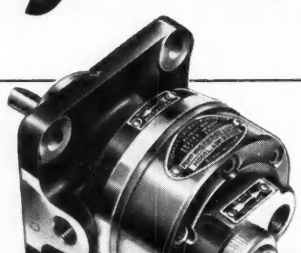

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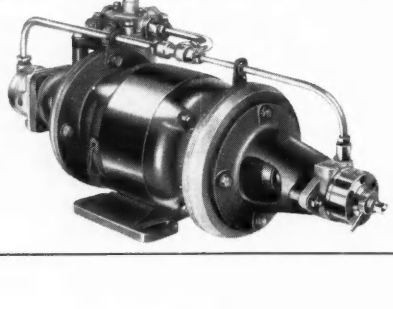

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Beech Aircraft Corporation, Wichita, Kansas, U.S.A., have established new facilities for their engineering division at Citizens Building, Boulder, Colorado. The new facilities will deal with military, commercial, missiles and technical assignments.

The 1955 edition of the **Canadian Trade Index** is just off the press. This volume, which contains a mine of information in more than 1,100 pages, is available from the Canadian Manufacturers' Association, 67 Yonge Street, Toronto 1, Ontario, at $7.50 per copy.

The 1955 edition could well be considered a key to Canada's industrial expansion. Its many features include an alphabetical list of more than 10,000 manufacturers with addresses, branches, principal products, export representation, trademarks and brands; a classified directory of products made in Canada, listing the names of the makers; informative illustrations in hundreds of display advertisements which supplement the alphabetical and classified listings; a directory of exporters of agricultural produce and allied lines, and a special section on export methods and services, which gives basic information on markets, financing, insurance, documentation, etc.

The Index contains in its regular editions a cross-reference index in French. There is also a limited edition with Spanish and Portuguese indexes for convenience to the Latin-American trade.

Imperial Chemical Industries Limited are making good progress with a new plant at Hillhouse, Lancashire, for the production of "Fluon" polytetrafluoroethylene. When completed, this will have a capacity of about 200 tons, which will be achieved in two stages. The first stage, due in January 1956, will mean that annual production of polymer is stepped up from 25 tons to 100 tons. The final 200-ton stage should be reached later in 1956. It is also planned to extend the present range to include an extrusion grade and special dispersions.

I.C.I. hopes to reduce the price of "Fluon" later this year or early next year.

Bakelite Limited have announced the conclusion of an agreement with Union Carbide Limited under which Bakelite Limited will market polyethylene plastics produced in the United Kingdom by Union Carbide Limited. The sales organisation of Bakelite Limited will be available for sales of this polyethylene both at home and in export markets.

Union Carbide Limited are constructing a plant at Grangemouth in Scotland to produce polyethylene of the same quality and types as that now made in the United States by Union Carbide & Carbon Corporation, who are the largest manufacturers of polyethylene in the world. The plant is expected to come into operation in the third quarter of 1957, but in the meantime Bakelite Limited will have available quantities of imported polyethylene for sales development purposes.

Designed to extend their activities in the field of chemical cleaning for industrial and marine equipment, **Houseman and Thompson Ltd.,** of D. M. House, Jesmond Road, Newcastle upon Tyne, 2, have opened a factory at Smeaton Street, Willington Quay, Northumberland.

The 10th International Fair of Ghent, Belgium, will be held from 10th to 25th September, 1955. This year's Fair will include an exhibition of laboratory equipment, printing, paper and allied trades exhibition and an exhibition of photography, cinema projection and television.

The Applications of Stress Analysis. The Ninth Annual Conference of the Stress Analysis Group will be held on September 28, 29 and 30, 1955, at Stephenson Hall, University of Sheffield. It will take the form of a general conference on the applications of stress analysis. Papers presented will include some from foreign visitors, and arrangements have been made for visits to local laboratories and works.

Further particulars and enrolment forms may be obtained from the Secretary, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

AUTOMATIC CONTROL IN THE PROCESS INDUSTRIES

A joint conference of The Institution of Chemical Engineers and The Society of Instrument Technology will be held in the Grand Hall, Caxton Hall, Westminster, London, S.W.1, on Tuesday, October 4, 1955.

There will be morning and afternoon sessions for the presentation of papers and ample time will be allowed for discussions.

The conference will cover a number of aspects of automatic control in relation to the design and operation of process plant. The programme will develop a direct and fundamental approach for the benefit of those without specialized knowledge of the field and will clarify terminology, definitions, and scope. Particular emphasis will be laid on the presentation of data in relation to practical installations and applications, without undue comment on instrument design or construction. This provisional programme includes the following papers :—

Fundamentals of automatic process control, by R. S. Medlock; The dynamics of process plant, by J. McMillan; Automatic process control and chemical engineering, by B. W. Balls and A. H. Isaac; Automatic control applications in industry: (i) Automatic control in the steel industry, by B. O. Smith; (ii) Automatic control of batch processes, by W. A. Goldstein; (iii) The temperature control of large storage tanks, by W. A. J. Preece; (iv) Automatic control in the pulp and paper industry, by N. C. Underwood; The economics of process control, by S. W. J. Wallis; and The development of modern control technique and the pattern of future development, by A. J. Young.

Further details can be obtained from The Institution of Chemical Engineers, 56 Victoria Street, London, S.W.1, or from The Society of Instrument Technology, 184 Sherwood Park Road, Mitcham, Surrey.

BIF ELECTRICAL SECTION TO BE IN LONDON

An electrical exhibition will be staged in London as part of next year's British Industries Fair. It will be held in the Grand Hall, Olympia, from April 23 to May 4, 1956.

At Olympia there will be 100,000 square feet of exhibition space available for the display of a wide range of electrical products, from power station and industrial plant equipment to lighting and domestic appliances.

Letters of invitation, space application forms and an illustrated leaflet are being sent to more than 1,000 electrical firms this month.

The decision to transfer the electrical section of the BIF from Birmingham to London has been made in response to views expressed by large sections of the electrical industry. In planning the change British Industries Fair Ltd. have had the encouragement and support of the British Electrical and Allied Manufacturers' Association and of other manufacturers' organisations.

Commenting on the change, Mr. Kenneth Horne, managing director of British Industries Fair Ltd., said, "This will be a wonderful opportunity to show the world the great advances that are being made in electrical invention and development. I am confident that, with the support of the industry, we shall be able to make the electrical section a credit to Britain and a major attraction of the London BIF."

Although the electrical section will be at Olympia, those electrical firms who still wish to exhibit in Birmingham will be able to do so. Technical products such as chemicals, office appliances, scientific instruments and electrical equipment will be on display at Olympia. The engineering and hardware section will be at Castle Bromwich, Birmingham.

COMBINATION BAR AND CONTINUOUS ROD MILL

Samuel Fox and Co. Ltd., of Stocksbridge, near Sheffield, are to spend nearly £2½ million on a new combination bar and continuous rod mill and associated bar heat treatment plant. Completion of the project is expected in two years' time. Provision is being made in the initial layout for the erection of an additional mill and for the extension of the new bar treatment plant should these developments be required at a future date.

The mill will roll bars and rods in alloy, high carbon and stainless steels from ·212 in. to 2½ in. diameter and equivalent sizes in squares and other sections, including spring flats. Essentially a high quality installation designed for maximum flexibility of operation, it will reduce normal re-rolling defects such as seams, laps and decarburization to a minimum.

Intended to replace an existing looping mill and a 14 in. double-duo mill at the Stocksbridge works, the new bar and rod mill is being supplied by The Brightside Foundry and Engineering Co. Ltd., Sheffield.

Billets destined for rolling in the mill will first be charged into an oil-fired heating furnace of 25 tons per hour capacity. This furnace is of the continuous pusher type. Complementary batch furnaces will provide heating facilities for special qualities of steel, without interrupting production from the continuous furnace.

The first section of the mill consists of a three-stand 18 in. mechanised roughing train, with two stands three-high and the third stand two-high, all driven from one 1500 hp a.c. motor. This is followed by a 14 in. single stand two-high mill, with a 350 hp d.c. variable speed motor.

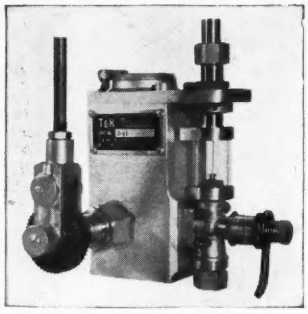
Four 11 in. two-high stands arranged in pairs form the intermediate train, each stand being driven by a 350 hp d.c. motor. Next comes an 11-14 in. cross-country mill of four two-high stands, with individual 350 hp d.c. motors to each stand, as in the intermediate train. When rolling bars, the 14 in. stands will be used for the larger sizes and the 11 in. stands for the smaller sizes. All sizes of bar will be delivered in straight lengths to a cooling bed and two bar reels are provided to coil all sizes up to 1 in. diameter or equivalent. When rolling rod, the 11 in. stands will be used as an intermediate train, delivering the material to the continuous finishing train.

This continuous finishing train consists of a six-stand alternate vertical and horizontal 10 in. mill, designed for rolling all rod sizes. The train is furnished with rod reels, the finished coils being delivered on to a system of cooling conveyors common to the bar reels. This mill is equipped with 250 hp d.c. motors to each stand and can roll at speeds in excess of 3000 ft per minute.

All the electrical equipment for the complete mill installation is being supplied by Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester.

In the bar heat treatment section of the new plant, facilities will be available initially for the annealing and heat treating of 14,700 tons of material per annum. Equipment to be installed includes two furnaces of 10 tons capacity and four of four tons capacity, the latter being served by a floor type charging machine. Coke oven gas firing will be adopted, with the exception of one of the four-ton furnaces, which will be electrically heated. Oil and water quench tanks, straightening, reeling and shot blasting equipment are among other facilities in this section, where bars will also be cut to length and inspected prior to dispatch.

Overall dimensions of the buildings housing the mill and heat treatment section will be 950 ft by 275 ft, being substantially brick-faced on the south elevation and end gables, with dwarf brick walls and sheeting on the north elevation. There will be three main mill bays and three bays in the heat treatment section, which is attached to the mill within a common building plan. A double-thickness



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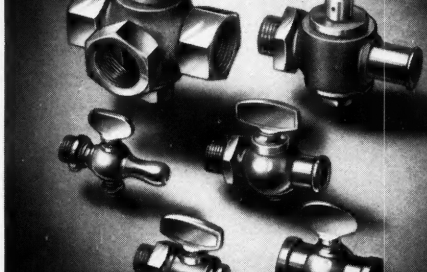

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roof will give the necessary insulation, while adequate natural light will be provided through side walls and roof. Four points of railway access will deal respectively with incoming billets, the dispatch of coiled material, the dispatch of straight bars direct from the mill, and the dispatch of bars from the heat treatment section. Main contractors for the erection of the new buildings are the United Steel Structural Company, Limited, Scunthorpe.

NEW ANHYDRITE MINE

A new anhydrite mine has recently been opened at Sandwith, near Whitehaven, on the west coast of Cumberland, on what are claimed to be the richest and most extensive seams of anhydrite in Britain. This mineral is one of the raw materials from which sulphuric acid and cement are manufactured.

Because of apparently dwindling sulphur resources in the United States in 1951, the United States Government seriously restricted exports and since the United Kingdom was dependent upon American elemental sulphur for half its sulphuric acid production, the British Government initiated an investment programme to make greater use of indigenous raw materials such as anhydrite in sulphuric acid manufacture. Marchon Products Ltd., chemical manufacturers, located deposits of anhydrite in the vicinity of their Whitehaven factory and decided to build a sulphuric acid and cement plant using the mined anhydrite as the raw material. To do this, a new company, Solway Chemicals Ltd., was formed, Marchon Products Ltd. retaining the controlling interest.

The mine has been designed to produce 7000 tons of anhydrite every 5-day week at 8 hours a day, and when the new plant is in full operation at the end of the year, it is estimated that at least 90,000 tons of sulphuric acid, and a similar quantity of cement, will be manufactured annually. Deposits at Whitehaven are so vast that supplies are expected to last for several hundred years. Inside the mine the pillar and stall method of extracting is used, only 60% of the mineral being taken, the remaining 40% being left as pillars to ensure that there shall be no disturbance of the surface above the workings. The face is drilled in a fixed pattern by electric rotary drills supported on a specially designed caterpillar track carriage, and the holes are charged with explosive and fired by milli-second delayed detonator. Each blast produces about 100 tons of anhydrite, which is loaded out by caterpillar mounted electric Eimco shovels into a new type of diesel driven dumper made by Muir-Hill. The dumpers tip the anhydrite into hoppers formed in the rock underground, and feeders carry the anhydrite from the hoppers on to the conveyor belt, which discharges directly into the screening and crushing system on the surface. The mine is already producing about 4000 tons a week.

The power supplies to the electrical equipment of the mine have made necessary the installation of nearly 5000 yards of 660-volt and 3300-volt cable to supply the conveyor heads and transformers, and 1200 yards of 660-volt cable for supply and lighting in the brake house which controls the movement of railway wagons to and from the mine. The electric rotary drills, mounted on caterpillar track carriages, are supplied with current via 1050 yards of 91/·018" trailing cable. All these cables, together with plastic types for use in the new chemical plant, and H.D. cadmium-copper wire for signalling purposes in the mine, were provided by British Insulated Callender's Cables Limited in addition to capacitors for power factor correction.

TITANIUM PROJECT IN THE UNITED STATES

Imperial Chemical Industries Limited and Columbia-Southern Chemical Corporation of Pittsburgh, U.S.A., have submitted a joint application to the United States Government for a contract under which the Government would undertake for a 5-year period to purchase 5,000 short tons per annum of granular titanium metal.

The companies stated that they have completed arrangements for the introduction into the United States of a granular titanium process not at present employed there and would also make available to fabricators techniques not at present known or employed in the United States.

If a contract is awarded in pursuance of their application, I.C.I. and Columbia-Southern Chemical Corporation will form a jointly-owned subsidiary for the purpose of producing granular titanium metal by I.C.I.'s sodium reduction process. The parent companies will each hold a 50 per cent. interest in the new company, which would be known as Columbia Titanium Company. The plant would be built at Natrium, West Virginia, and would have a capacity of 5,000 short tons per annum. The cost of the proposed granular titanium metal plant will be in the region of U.S. Dollars 10,000,000.

I.C.I.'s patent position and production experience have an unusually broad base through their experience of chemical and metallurgical technology. Their patent and process knowledge extend from the production of granular titanium metal by their new sodium process, to melting, scrap recovery, alloying, testing, jointing and fabrication, in the latter of which particularly they are favourably placed by virtue of their wide experience in non-ferrous metal technology.

Columbia-Southern's contribution to the proposed joint enterprise lies in the production of titanium tetrachloride, from which granular titanium metal will be made. Columbia-Southern, which is itself one of the leading American producers of chemical products and is a wholly-owned subsidiary of the Pittsburgh Plate Glass Company, has been engaged in research on the chlorination of titanium-bearing ores since 1937. It has established a broad patent position in this field and today licenses other companies under Columbia-Southern patents.

CONTRACTS

W. G. Bagnall Ltd., of Stafford, have received an order from the National Coal Board for two diesel mechanical shunting locomotives for use at the new Lea Hall Pit near Rugeley, in the Cannock Chase Area. The locomotives, which will be powered by National "M4AA5" diesel engines developing 220 horsepower at 1500 rpm, are of the 0–6–0 type suitable for 4′ 8½″ gauge track. These locomotives weigh 28 tons in working order and are capable of hauling trains of 1,000 tons gross weight on the level.

The mechanical transmission includes a Fluidrive traction type hydraulic coupling; Layrub shaft with flexible couplings; Self Changing Gear Company's four-speed, air-operated gear box; and Alfred Wiseman air-operated reverse and final drive gear box. From the final drive gear box the drive is taken by jackshafts and coupling rods to the wheels.

Steam locomotives built by Bagnalls have been used in British collieries for many years. Recently three 16″ 0–6–0 steam locomotives were delivered for the N.C.B., two going to Hem Heath (Stoke-on-Trent) and one to Rawdon Pit. Nearing completion in the shops are two diesel electric, 0–6–0 shunters powered by National "R4AA6" diesel engines developing 366 horsepower, which are being built to the designs of Brush Bagnall Traction Ltd., for the N.C.B.'s South Wales area.

An order valued at over £285,000 has recently been received by **Metropolitan-Vickers** (through Australian General Electric Pty. Ltd.) from the State Electricity Commission of Victoria. It covers a 20-MW 3000-rpm low-pressure turbine-generator set for installation at the Commission's brown coal briquetting factory at Morwell. The set will include a double-flow low-pressure turbine designed to use surplus exhaust steam from two Metropolitan-Vickers 30-MW back-pressure turbine-generator sets already installed at the same station.

Originally it was planned to use the exhaust from the larger turbines as process steam in the briquetting plant, but owing to financial restrictions the construction of this plant will not go forward as quickly as anticipated; it was therefore decided to convert the resultant surplus steam into electrical energy which will be fed into the Electricity Commission's system. Approximately 420,000 lb/hr of surplus steam will be passed into the new turbine at 27½ psig and 299° F.

The turbine will be coupled to an air-cooled a.c. generator designed for a power factor of 0·7; generation is at 11,000 V 50 c/s.

Both the turbine and the generator will be made at the M-V Trafford Park Works. The associated condenser, operating at a vacuum of 27½″ Hg, and the feed water heaters will be manufactured to Metropolitan-Vickers design in Australia.

The British Thomson-Houston Export Company has obtained an order through A.E.I. (India) Ltd. worth approximately £300,000 for converting plant, D.C. switchgear, and control gear for the first stage in the main line electrification of the Eastern Railway of India.

The order covers six substations and three track section cabins on the main line from Calcutta (Howrah) to Burdwan—a distance of 66 miles, and one track cabin at Karmarkundu which is on the branch line to Tarakeswar.

The converting plant consists of eight 2500-kW and four 3000-kW, 3000-volt, 12-phase pumpless steel-tank mercury arc rectifier equipments, each including two withdrawable truck-mounted rectifiers, an outdoor transformer, and a control cubicle. These are to be installed in two triple-unit, two double-unit and two single-unit substations.

The D.C. switchgear for the rectifiers, track feeders and track sectioning cabins comprises high-speed circuit breakers which, with their associated control gear, are mounted on withdrawable trucks. These will be housed in concrete cells.

The order also includes low tension switchgear and certain substation auxiliaries.

Marconi Instruments Ltd., St. Albans, Herts., have received from the English Steel Corporation Ltd. and the United Steel Companies Ltd. contracts for the supply of 250 kV Constant Potential X-ray Units to their works at Grimesthorpe and Distington, respectively.

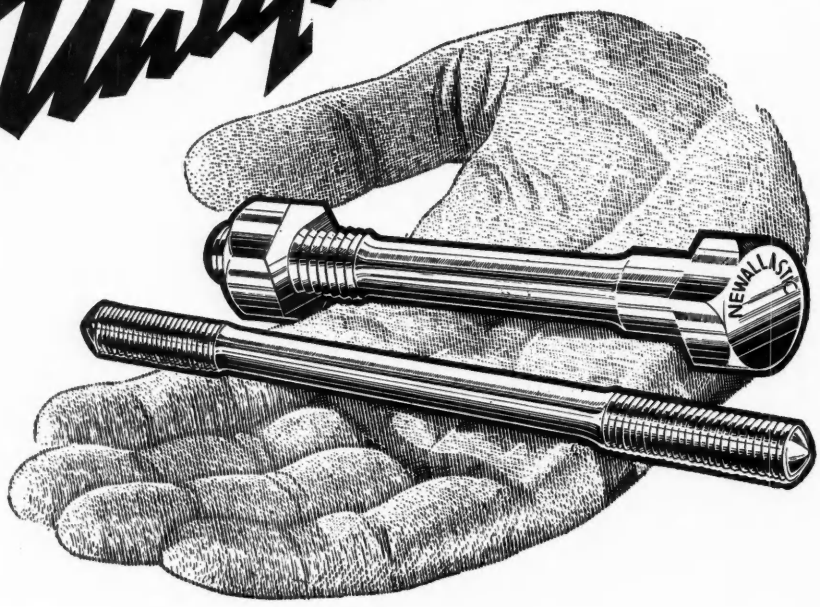
The equipment for Grimesthorpe comprises a constant potential high-tension generator, a control unit, an oil cooler, and an oil-cooled shock-proof tubehead with a special turntable mounting for fitment to a girder suspension system.

The Distington equipment is electrically similar, but is mounted on a specially designed two-ton trailer to permit the easy radiographic inspection of welds and castings, irrespective of size. The control unit is installed in a lead-lined protective compartment, while at the opposite end is the tubehead and tubestand.

These equipments have a voltage range of from 30 to 250 kilovolts, enabling steel of up to four inches in thickness to be penetrated. The constant potential generators enable the whole of the high voltage energy to contribute to X-ray generation, ensuring maximum X-ray output and hence exposure times shortened by half.

Lurgi Gesellschaft fur Chemie und Hüttenwesen m.b.H have received through their representatives, D.M.M. (Machinery. Ltd. of London, a contract valued at £189,000 for four Lurgi-Frodingham sinter coolers for the Appleby-Frodingham Steel Company's Apex Plant at Scunthorpe, Lincs. This is a repeat order for sinter coolers similar to those recently installed at the Appleby-Frodingham Seraphim Plant.

Unique



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POSSILPARK GLASGOW · N

The Central Electricity Authority has placed in June contracts for power stations, transformer stations and transmission lines for the aggregate amount of £16,647,000. The firms who have been awarded the principal contracts include Sir Robert McAlpine and Sons Ltd., Hackbridge and Hewittic Electric Co. Ltd., John Thompson Water Tube Boilers Ltd., George Wimpey & Co. Ltd., John Thompson Industrial Construction Ltd., C. A. Parsons & Co. Ltd., Foster Wheeler Ltd., Mitchell Construction Co. Ltd., Metropolitan-Vickers Electrical Co. Ltd., General Electric Co. Ltd., Worthington-Simpson Ltd. and Sulzer Bros. (London) Ltd.

The English Electric Co. Ltd. has received an order from the Power Authority of the State of New York for two large transformers to be used in connection with the St. Lawrence Power Project.

A hydro-electric power-station is now being erected on the St. Lawrence River jointly by the Canadian and United States Authorities. For the Canadian side the English Electric Company of Canada Ltd. is building in Toronto the water turbines to the designs of The English Electric Co. Ltd. in England.

On the American side, part of the power generated will be stepped-up to 115 kV and part to 230 kV. The transformers which the company is now to build will couple these two busbars together for the inter-change of power. They have an output of 120,000 kVA with a voltage ratio of 230/115 kV with the windings auto-connected. A tertiary winding is provided for the supply of power at 13·8 kV. They are three-phase units and the cooling is of the OFW type (pumped oil circulation through water coolers). The main windings will be impulse tested at a level of 900 kV. These transformers are similar to an 80,000 kVA unit built by the Company and now in service at the Folsom Dam in California. They will be arranged so that a group of four generators is connected to each bank of transformers.

Davy and United Engineering Company Limited have received an order worth some £550,000 to build a new 18″ Morgan Continuous Skelp and Strip Mill for the steelworks at Newcastle, New South Wales, of Broken Hill Proprietary Co. Ltd. This mill will primarily be engaged on quantity production of high quality steel strip for subsequent processing into tubes—strip for this purpose is known in the trade as skelp—and medium-width strip for a variety of other applications.

A mill of this size and type can produce in excess of half-a-million tons of strip a year and its installation is another indication of the steady expansion programme being pursued by Australia's own steel industry. The Broken Hill mill will consist of fourteen stands and will be supplied with a considerable amount of auxiliary handling and control equipment. Delivery is expected to be made in early 1957.

Orders for turbo-alternator sets totalling some £2½ million have been placed with **The General Electric Co. Ltd.** by the Central Electricity Authority. They comprise one 120 MW and two 60 MW sets, in which the alternators will be direct-cooled by hydrogen at 30 psig. In this system of cooling, hollow copper conductors are used for the rotor winding through which the hydrogen is forced, thereby greatly improving heat dissipation from the rotor and resulting in a marked reduction in the overall dimensions and weight of the machines.

Steam conditions in the reheat-cycle turbo-alternator of the 120 MW set will be 1500 psig, 1000° F, with reheat to 1000° F. The machine will have HP, IP, and LP cylinders arranged in a single line, with turbine and generator rotors rigidly coupled and a single thrust bearing. After expansion to 415 psia in the HP cylinder, steam passes to the reheat section of the boiler at a temperature of 700° F, and is returned to the IP turbine at a pressure of 375 psia and temperature of 1000° F. After expansion in the IP turbine, steam passes through twin overhead pipes to the double-flow low-pressure turbine. The rating of the direct-cooled alternator is 150,000 kVA at 0·8 p.f.

This contract includes the supply of a condenser with a cooling surface of 70,000 sq ft, and a six-stage feed heating plant. For an output of 120 MW the designed vacuum will be 28·9 inches of mercury and the final feed temperature 435° F.

The two 60 MW sets will operate at steam conditions of 925° F and 900 psig, vacuum at full output being 28·9 inches of mercury. The turbines are a two-casing design similar to those previously supplied to Uskmouth, Ince and Hams Hall stations, and the direct-cooled alternators are rated at 75,000 kVA at 0·8 p.f.

BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 2 Park Street, London W.1)

Wrought aluminium for electrical purposes—wire. B.S. 2627 : 1955 refers only to wire used for electrical conductors such as overhead transmission lines, insulated cables, or windings for rotating machinery or transformers ; and is suitable for controlling the quality of wire supplied for electrical components made to other British Standards, such as B.S. 215 'Hard-drawn aluminium and steel-cored aluminium conductors ', and B.S. E21 ' Electric cables for aircraft '.

Wire for general engineering and other purposes is specified in B.S. 1473 ' Rivet, bolt and screw stock for forging ', and B.S. 1475 ' Wire ', which form part of a comprehensive series of standards for wrought aluminium and aluminium alloys for general engineering purposes (B.S. 1470–77), which are at present under revision.

The present standard is the first of a similar series of standards for wrought aluminium and aluminium alloys for electrical purposes. The system of nomenclature adopted in this standard is cognate with that employed in the general engineering series. Price 2/6d.

Classified Advertisements

The rate for all classified advertisements is 6d. per word ; in bold print 9d. per word ; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

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REPRESENTATIVE (35/40) required to sell non-ferrous centrifugal castings. Engineering training or background required. Must be able negotiate at high level. Good remuneration and prospects for first class man. Write **Metals & Alloys,** Minworth, Birmingham.

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NON-FERROUS FOUNDRY MANAGER (Directorship later) required, preferably experienced technically and commercially in centrifugal casting. Exceptional remuneration and an interest in financial results. Apply in confidence, Chairman, Metals & Alloys, Ltd., Minworth, Birmingham.

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Applications are invited for positions in our Production organisation which is engaged in the manufacture of precision electromechanical/electronic equipment. Applicants should hold a degree or diploma in Electrical Engineering, Mechanical Engineering or equivalent, but consideration will be given to applicants holding a H.N.C. in Engineering and who have completed an engineering apprenticeship. The vacancies are for :—

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TECHNICAL PROJECT ENGINEERS who do not possess the necessary practical experience for (B) but have a flair for production matters and who would act as technical assistants to the Project Engineers in the first instance with a view to promotion to Project Engineers in due course.

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A YOUNG TECHNICIAN, either metallurgical or engineering training, is required for welding investigations in the A.P.V. Laboratories at Crawley. Candidates should be able to present some recognised qualification in either of the above subjects, together with practical laboratory or works experience. The salary paid will depend on age and qualifications and the post will carry profit sharing and pension rights. Housing at Crawley may be arranged for the selected candidate. Apply in own hand-writing as soon as possible to The Laboratory Manager, The A.P.V. Company, Ltd., Wandsworth Park, S.W.18.

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THREE 200 LB. FRICTION BOARD DROP HAMMERS for sale, by Taylor & Challen. Drop 42 in. Between guides 13¼ in. 400 lb machine also available. Weight 65 cwts. Photo : **F. J. Edwards Ltd.,** 359 Euston Rd., London, N.W.1. Euston 4681.

150 TONS × 120″ NEW HYDRAULIC PRESS BRAKE by Brauchli. Quick delivery. Built-in motorised pump. Between uprights 104″. Length of bed 120″. Stroke 3½″. Weight about 6½ tons. Steel plate construction. **F. J. Edwards Ltd., 359 Euston Road, London N.W.1.**

500 kVA. DIESEL GENERATING SET 400/3/50, complete installation : run only 2500 hours. **A. C. Dibley & Co. Ltd., 72 Granville Road, N.W.2.**

BOOKS RECEIVED

BDI—Germany Supplies. 1955 Edition. 2000 pages. Publishers: Federation of German Industries (BDI), Cologne, Germany. World Distributors: Uebersee-Post, Nuernberg, Germany. U.K. Agents: Overseas-Post, 16 Sheldon Street, Lonton, W.2. Price: 70/- ($10).

Since its first appearance, this official Export Register of the Federation of German Industries and the Federation of German Handicraft Organizations has established itself as by far the most representative and comprehensive survey of goods offered by the West German export industry. This new and enlarged edition, with something like 35,000 classified trade headings, is in every way a worthy successor, and should prove of great value in all markets.

The book is designed for easy and quick reference and is printed in English, Spanish, French, and German. It has been conveniently divided into sections, comprising an alphabetical index of German industrial products and trademarks; a list of export goods and their manufacturers, classified according to industrial groups; and a complete alphabetical directory of the German export industry, ncluding addresses, telephone numbers, etc.

Mathematics for Engineers (*Part I*). 9th Edition, 1955. By W. N. Rose, B.Sc., Eng.(London). 540 pp., 259 illustrations. Publishers: Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price: 21/-.

In this volume, one of the Directly Useful (D.U.) Technical Series, an endeavour has been made to produce a book embracing all the mathematical work required by engineers in their practice and by students in all branches of engineering science. For this reason, owing to the vast amount of ground to be covered, it has been found impossible to include the entire subject in one volume. Accordingly, it has been divided into two distinct parts, of which this volume deals fully with the fundamental rules and processes of algebra, plane trigonometry, mensuration, and graphs, while Part II covers calculus and its applications, harmonic analysis, spherical trigonometry, etc.

In this 9th edition of Part I, a general revision has been carried out, and a few minor alterations have been incorporated. However, the general plan and form of the book are the same as in the previous editions, so widely known and appreciated.

Engineering Dynamics. *Vol. I:—Theory of Elasticity; Vol. III:—Steam Turbines; Vol. IV:—Internal-Combustion Engines.* By C. B. Biezeno and R. Grammel. Publishers: Blackie and Son Ltd., 17 Stanhope Street, Glasgow, C.4. *Vol. I*, 320 pp., 103 illustrations, price 50/-; *Vol. III*, 276 pp., 101 illustrations, price 40/-; *Vol. IV*, 294 pp., 214 illustrations, price 50/-.

Textbooks as well as elementary lecture courses covering the syllabus of engineering mechanics must attach special importance to simplified, rather academic problems, the more difficult problems met with in engineering practice usually being omitted. For this reason, most technical colleges have instituted special courses in higher mathematics, dealing with the more complicated problems encountered by the practical designer or research engineer.

The present series of volumes is intended to serve a purpose similar to that of special lectures and represents, as it were, a continuation of the usual textbooks. It is therefore assumed that the reader has a grounding in elementary mechanics and the mathematics associated therewith. For the arrangement and treatment of the subject, the authors have kept in mind the belief that a technical problem is worth solving only if it can be applied in practice, and that a solution is complete only when all the details of the problem can be numerically evaluated with a tolerable amount of arithmetical work. However, in spite of the importance they have attached to numerical results, they give prominence to the methods of solution, and a whole chapter of each volume is devoted entirely to a study of methods. Furthermore, the authors have endeavoured to indicate for every problem the best and most complete solutions attainable by present-day methods.

Vol. II, "Elastic Problems of Single Machine Elements," will be issued shortly.

Centrifugal and Other Rotodynamic Pumps. 2nd Edition, 1955. By Herbert Addison, O.B.E., M.Sc., M.I.C.E., M.I.Mech.E. 540 pp., 275 illustrations. Publishers: Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price: 50/-.

In preparing the second edition of this well-known work, the author has successfully fulfilled his object of preserving the concise and direct style of presentation of the original. This new edition has been revised and enlarged, in accordance with the demands made by advances in practice. In addition, the Bibliography has received special attention and will undoubtedly reflect the recent efforts of pump designers and manufacturers, engineering consultants, and research specialists.

The range of the book, which deals with most of the questions likely to concern designers, manufacturers, and users of centrifugal pumps and allied equipment, is comprehensive—as indeed it must be, in view of the ever-widening field of application of such equipment.

With regard to the treatment of rotodynamic pumps as such, the author has tried to develop as far as possible suggestions recently put forward by various writers for the use of non-dimensional descriptive terms. As he rightly points out, "internationalism may be welcomed in technical works as much as elsewhere; and one of the best ways of encouraging it is to lower the barriers formed by conflicting systems of units."

LATEST INDUSTRIAL LITERATURE

1. Electric Motors for the Oil Industry. In a beautifully produced and illustrated 200-page publication, details are given of electric motors and associated equipment for the oil industry. Not only does this publication tell the oil-industry engineer of the many types of alternative equipment available, but it also gives detailed information designed to facilitate selection for any particular purpose. In this connection, engineers in the oil industry have to be particularly discriminating, and for this reason the publication co-relates design data with special requirements, such as protection against fire hazards. Reference is also made to the requirements of British and American inspection and standardization authorities.

There can be no doubt that this interesting publication should prove of inestimable value to engineering personnel in the oil and chemical industry.

2. Moving-Coil Relays. In an illustrated 4-page brochure details are given of a range of moving-coil relays with many interesting features. Accuracy is usually within $\pm$ 2% of the scale range at any point on the scale, and the relays can be manufactured to suit a variety of purposes, including d.c. overcurrent and/or reverse current; a.c. overcurrent; d.c. or a.c. overvoltage and/or undervoltage; overspeed and/or underspeed; under and over frequency; and earth leakage.

When specified, the coils are insulated and impregnated to suit normal tropical requirements. The range of types includes projecting and flush patterns, with or without flag indicator.

3. Free-Machining Stainless Iron. Full details are contained in a 12-page booklet of a stainless iron with excellent free-machining properties. This material contains approximately 0·10% carbon and 12 to 14% chrome, with a free-machining agent added in such a manner as not to have any detrimental effect on its performance.

This stainless iron is supplied in two conditions, i.e., heat-treated to 45/55 tons tensile, and to 35/45 tons tensile. Both conditions are equally free-machining. Furthermore, it can be ordered in a variety of forms, e.g., centreless ground, in lengths; cold-drawn, in coils and lengths; hot-rolled bars, in round, square, rectangular, and hexagon sections; and forgings, shaped according to requirements.

4. Metal Buildings. Neatly produced and illustrated, a 28-page brochure gives full details of the advantages offered by metal buildings, the basic design of which centres around prefabricated three-pin arches manufactured from cold roll-formed sections with an exceptionally high strength/weight ratio. These arches are delivered to the site in four parts, comprising two rafters and two legs. The buildings are manufactured from a high-tensile low-alloy steel with a corrosion-resistance factor of from 4 to 6 times greater than that of normal structural steel. Heavy grey-iron castings are used where the steelwork is in contact with the foundation.

One of the principal contributory factors to the low cost of these buildings is the use of an exclusive system of lining and insulation, which is incorporated into the structural framework, thereby eliminating the use of expensive interior scaffolding.

5. Low-Lift Electric Platform Trucks. Details are contained in an illustrated 4-page brochure of two low-lift electric platform trucks, with capacities of 2 and 3 tons respectively. These trucks, which are powered by a 12-V battery, have a travelling speed of 2 mph under full load.

Compact overall dimensions and the ability to steer through more than 180 deg. make these trucks very manoeuvrable. Furthermore, their weight—between 1270 and 1440 lb—permits their use on low-load floors and on the upper floors of many buildings.

6. Double-Ended Dry Grinder. A new 16-in., high-speed double-ended dry grinder, incorporating a new and approved system of dust control, evolved after more than two years of intensive research by the British Cast Iron Research Association, is described in an illustrated 4-page brochure.

The machine employs highly efficient external dust-control hoods, which are equally efficient on a worn wheel. Furthermore, no adjustment of any kind during the life of the grinding wheel is necessary to maintain effective dust control. The grinder has been specially designed to comply with the requirements of the Iron and Steel Foundries Regulations 1953, and particularly with reference to Regulation 7 (6), which is scheduled to come into operation on January 1, 1956.

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *NEW VACUUM-BRAZING CLADDING PROCESS*

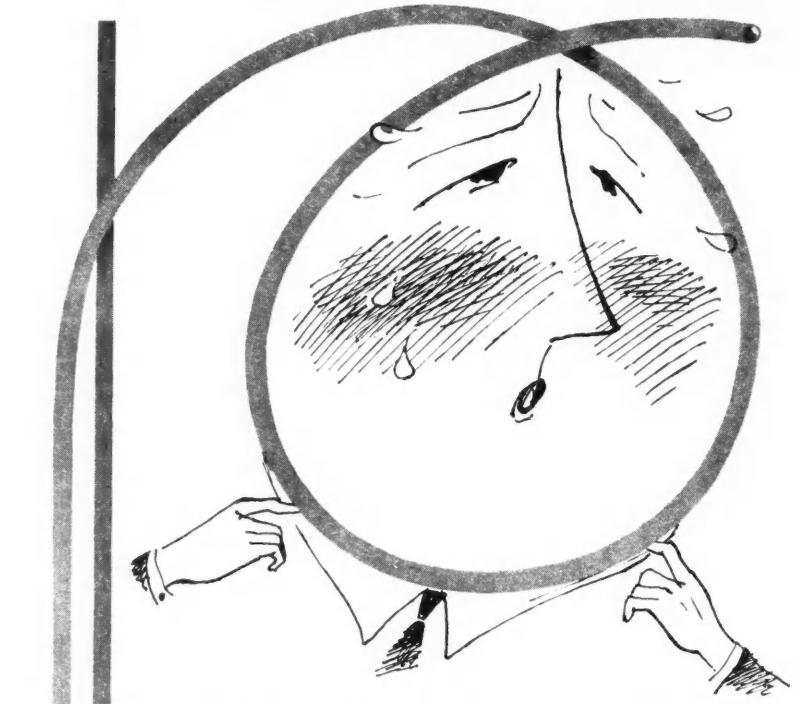
It is claimed that clad plate can now be made by a novel vacuum-brazing process, which can be used to produce metal combinations which cannot be obtained by any other cladding method. Thus, for instance, a stainless-steel sheet can be clad with a fine silver sheet. Since in the new process the metal composite is not reduced or deformed in any way during bonding, the service life of a corrosion-resistant layer is not reduced by the presence of areas thinned out during bonding. Because of the uniformity in layer thickness achieved, thinner cladding sheet may therefore be specified. Another advantage of the vacuum-brazing process is that the original surface finish of the individual sheets is not impaired. Thus, the satin-finish surface of a stainless-steel plate, free from imperfections, can be retained. The most widely used metal combinations are said to be nickel, nickel alloys, chromium steels, or chromium-nickel steels backed by carbon steel. The maximum size of clad plate produced in this way is claimed to be limited only by furnace dimensions. The clad sheets or plates can be subsequently fabricated by welding and by conventional hot- and cold-forming methods, such as rolling, pressing, and bending. The new process is carried out by placing a thin foil of brazing alloy between the plates to be bonded. Brazing materials used include pure copper, brasses, bronzes, and silver alloys. As the brazing alloy melts in the furnace, a vacuum of 29 to 30 in. Hg is drawn between the plates, so that they are forced together by atmospheric pressure. The vacuum then draws away any gases liberated at the interface, and oxidation of the bonding surfaces is prevented.

● *NEW WELDABLE HIGH-STRENGTH TITANIUM ALLOYS*

Two new high-strength titanium alloys have been developed for the purpose of finding a weldable material with properties equal to those of 8% magnesium-titanium alloy, which has unsatisfactory welding properties. One of the new alloys is an all-alpha titanium alloy in which the alpha-stabilizing elements are aluminium and tin. The other alloy is of the alpha-beta titanium type, in which manganese is the beta stabilizer and aluminium is the alpha stabilizer. Both alloys have been found to be readily weldable by the inert-gas-shielded non-consumable tungsten-electrode process. Several tests were employed to determine the weldability of these alloys, the most important being weld bend tests, tensile tests, and circular patch-weld restraint tests. In weld bend tests the alpha alloy proved slightly superior, but the minimum bend radius of the alpha-beta alloy could be improved by torch heating of the weld, and both alloys were considered highly satisfactory in this respect. In either alloy, welds in square butt joints gave weld efficiencies exceeding 100%, both at room temperature and at 700° F. In the circular patch-weld restraint test the welded alpha-beta alloy was found to develop transverse cracks through the weld approximately four months after welding. However, material which had been vacuum-annealed prior to welding did not develop cracks after welding. This improvement is ascribed to the removal of interstitional hydrogen, which creates an increasingly unstable condition with ageing. Vacuum-annealing of the sheet, which contains 133 parts per million of hydrogen, has therefore become common practice. The alpha alloy was not found to be as crack-sensitive as the alpha-beta alloy, and circular-patch specimens continued to be crack-free six months after welding.

● *DIRECT TRANSFORMATION OF HEAT INTO ELECTRICAL ENERGY*

The problem of the direct transformation of thermal energy into electrical energy for the purpose of power generation is one of long standing, and many unorthodox solutions to this vital problem have been proposed, though so far none has proved suitable for the production of power on a large scale. However, any solutions proposed, no matter how unlikely their introduction into practice may appear at present, may be of considerable interest. A recent proposal in this field appears to have a special appeal, because it deals with a mode of approach which has not received much attention of late but which may come into prominence in connection with nuclear developments. According to this proposal, caesium vapour or gas is produced in a pressure vessel by heating and evaporating the caesium between two electrodes by means of an electric current. From this pressure vessel the caesium vapour, in an ionized state, is passed through a jet into another vessel, preferably of a flat shape. This vessel is evacuated and contains two collector electrodes, which collect positive ions and electrons respectively. Before passing between the electrodes, the



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Consider: through the walls of a one-foot length of uninsulated four-inch bore pipe, carrying steam at 500° F, you waste the heat produced by one ton of coal, every year! If this inefficiency gets *you* hot under the collar, how do you think your steam pipes feel—under their collars and flanges, round their bends and valves? If they're hot to you, you're wasting fuel by the ton. And that's where a little Fibreglass can save you a lot of money. In rigid sections, compact and lightweight, thickness for thickness, there's nothing in the world to beat it for efficiency. Moreover it is easily mitred to proof awkward corners against heat leaks. Other, even more difficult situations, and temperatures above 500° F and up to 900° F, are covered by Fibreglass in *flexible* sections.

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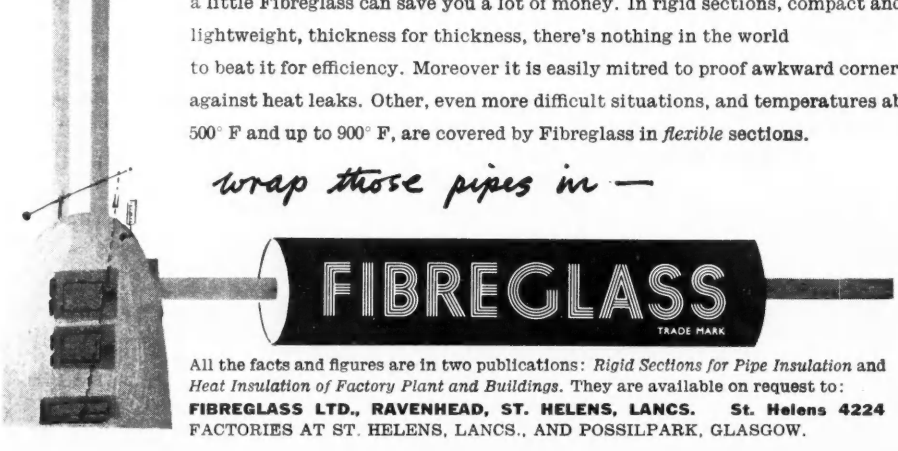

All the facts and figures are in two publications: *Rigid Sections for Pipe Insulation* and *Heat Insulation of Factory Plant and Buildings*. They are available on request to:
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high-speed jet of caesium vapour is passed through a magnetic field, which acts on the charges in the jet and directs the positive ions and the electrons towards the appropriate electrode. The second vessel is connected to a vacuum pump. Since a single generator of this type will deliver current at a relatively low potential, it may be possible to combine a number of vessels and jet systems in series, with the respective electrodes also connected in series. By applying a continuous magnetic field direct current will be produced. However, the use of an alternating magnetic field as an alternative is also envisaged, and in this case alternating current will be produced. According to the inventor, other gases or vapours may be employed instead of caesium.

● *HELICOPTER LAMP*

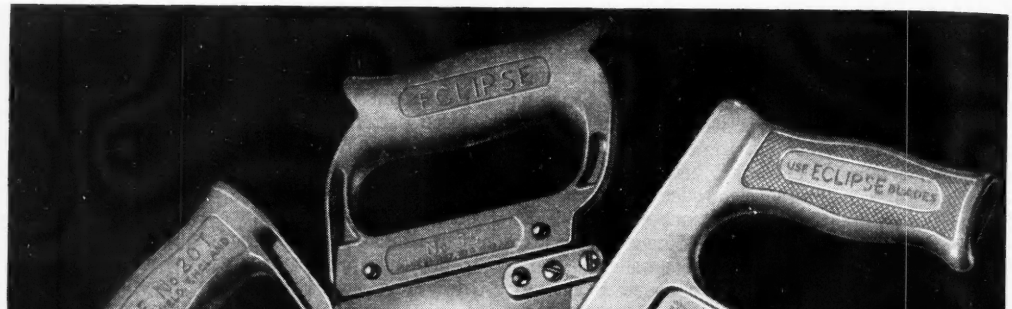
A new aircraft lamp which can withstand centrifugal forces up to 1000 *g* has been developed primarily for installation in helicopter blade tips. Helicopters have unusual manoeuvring characteristics and therefore require special identification lights to distinguish them from other types of aircraft. The biggest problem in the development was in making a lamp with a reasonable life span at the high centrifugal forces existing at the blade tip. These forces can exceed 700 *g* on present helicopters, and reach 1000 *g* under certain speed conditions. The original report points out that exhaustive tests were made on a series of gradually improved designs, until the final result was a lamp with closely spaced, rigidly supported filament wires. Actually, in order to provide the light intensity required, the lamp has two tightly coiled filaments in series. The lamp produces some 35 candlepower, and reflectors in the blade tips increase the effective light output approximately nine times. A clear plastic housing in the blade tip encloses the lamp and is designed to follow the blade contour as closely as possible, so as not to affect the aerodynamic blade design. The lamp operates at 12 V and is connected to its supply source by a system of silver slip-rings and brushes at the blade hub, the leads running inside the hollow blade. Experimental work has been done in automatically switching on and off green and red lights in the blade tips, so that they create a green half-circle on the right side of the helicopter and a red arc on the left.

● *IMPORTANCE OF THE SUBSTRUCTURE OF METALS*

A research report emphasizes that the effect of substructure upon the physical properties of metals has often been overlooked. Substructure is the structure within grains or single crystals of metals. Generally, a polycrystalline piece of pure metal is thought to be made up of an aggregate of grains, which are nearly perfect crystalline arrays of atoms. In single crystals, where there are no interfering grain boundaries, the regularity of the atomic arrays is considered to be uninterrupted throughout the specimen. The regularity, of course, has slight imperfections, owing to the presence of impurity atoms, vacancies, or dislocations. Veining in ferritic steel or a regular closed pattern, such as that shown in aluminium and zinc in the sub-grain structure, can have considerable effect on the physical properties of metals, particularly at low temperatures. Another field in which substructure has considerable effect is in diffusion results. In single crystals of zinc a substructure appears which can be revealed only by etching, since the disregistry is only a matter of a few seconds of arc. This structure results in anomalous self-diffusion values, and at low temperatures grain-boundary diffusion becomes more important than volume diffusion. It also seems reasonable to suppose that sub-grain boundaries should act as easy paths for diffusion. The report states that further work is being carried out to determine the detailed nature of sub-grain boundary and to evaluate its effect on the physical properties of metals. The presence of substructures should always be looked for in metallurgical experiments and their possible effect should be considered.

● *OXYGEN IN GREY CAST IRON*

It is known that grey cast iron, of normal silicon content, contains oxygen rarely exceeding 0·004% by weight when produced. At the same time, there have been many reports of cast-iron analyses showing oxygen contents as high as 0·047%, particularly in castings which have been in use for many years. The question has therefore arisen as to whether modern production methods are different from earlier methods, or whether there is any other cause for this discrepancy. In order to solve the problem attempts were recently made to produce high-oxygen cast iron. In the course of this investigation three flake-type cast irons and one cast iron containing nodular graphite were studied for a period of one year after production. Examinations were made at intervals during this period. At the commencement of the period, the flake-type irons contained 0·0024 to 0·0037% oxygen and the nodular iron 0·0011%. One flake-type iron reached 0·004% oxygen content in one week, while the other two exhibited the same amount by the end of the first month. By the end of the year, the three flake irons had oxygen contents of 0·007, 0·0110, and 0·0160%. The nodular iron increased its oxygen content by only 0·0025% during the year. The investigators concluded that the answer appears to lie in the fact that grey cast iron can absorb oxygen when stored under average atmospheric conditions. This would explain many of the reports of high oxygen contents. The mechanism by which the metal absorbs oxygen, however, can as yet only be surmised, and further studies of this phenomenon will be required.



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● *SUPER-PRESSURIZING METHOD OF MANUFACTURING HIGH-PRESSURE PIPES AND CONTAINERS*

A recent patent describes a new method for the manufacture of high-pressure pipes and containers by the super-pressurizing method. Super-pressurizing consists of placing the hollow body in a mould corresponding to its external shape, but of larger dimensions, and then subjecting it to a sufficiently high internal pressure, so as to exceed the elastic limit of the steel and expand the wall until it comes into contact with the mould. In this manner, the wall of the body undergoes a permanent deformation, and its dimensions are modified, while at the same time the elastic limit of the material is increased. The patent claims that it is not essential to make the mould completely envelop the hollow body to be super-pressurized and that it is possible to obtain the same result by using, instead of a continuous mould, a number of hoops spaced along the hollow steel cylinder. In order to make the hoops withdrawable, movable spacers are inserted between the rings and the hollow cylinder. The inventor states that, because of the rigidity of the metal, the expansion effect is transmitted to the wall of the cylinder in the gaps where it is not supported by the mould rings, without causing deformations of the walls in the form of bulges or irregularities between the rings. It is also stated that longitudinal shortening caused by super-pressurizing is often less than the relative elongation of the wall corresponding to the radial expansion. In order to avoid the resultant reduction in wall thickness, a complementary longitudinal compression in the course of the super-pressurizing process may be exerted. The effect of this compression can be so chosen that it exactly compensates for the loss in wall thickness which would be caused by super-pressurizing alone.

● *DIELECTRIC STRENGTH OF THERMOSETTING LAMINATES*

Thermosetting laminated plastics are used extensively for electrical insulation because of their unusual combination of electrical, mechanical, and chemical properties. In addition to being excellent insulators, these materials are also mechanically strong, light in weight, and easy to fabricate. They resist chemical corrosion, moisture, ageing, heat, and temperature deterioration. Since long service without breakdown is a primary requirement of electrical insulating materials, determination of the endurance limit is quite essential. This can be measured by stressing the laminate with voltages less than the short-time value and recording the results at each voltage. When the maximum voltage which can be applied for an indefinite time without breakdown has been found, the endurance limit of dielectric strength has been established. In the case of laminates, differences between the dielectric breakdown properties parallel with and perpendicular to the laminations are sufficient to warrant investigation of behaviour for each direction. When selecting thermosetting laminates to be used as a dielectric medium, it is important to know the temperature at which the equipment is to be operated, the atmospheric conditions to be encountered, the mechanical stress, and the dielectric stress to be applied. Where dry conditions prevail and the mechanical strength requirements are not severe, paper-base laminates are very satisfactory. For humid conditions it would be advisable to use the more water-resistant paper-base grades with higher resin content. For dry conditions requiring high mechanical strength it may be necessary to use a fabric grade having a cotton base and bonded with phenolic resin, while under continuous humid conditions requiring high mechanical strength it may be necessary to use a nylon-fabric-base material bonded with phenolic resin. Where arc resistance is important, a glass-base laminate should be used.

● *DYNAMIC LOADING OF GEAR TEETH*

A recent research report analyses the dynamic loading of spur and helical gear teeth and presents equations which make it possible to predict total dynamic loads for both heavily loaded and lightly loaded gear teeth. The term " heavily loaded gear " is applied to those gears in which the deflection due to the steady power is equal to or greater than the manufacturing tooth error. The dynamic load equations for such gears indicate that the dynamic load varies from a minimum of one half the effective tooth error (static deflection plus manufacturing error) multiplied by the elastic tooth constant, to a maximum value equal to the effective error multiplied by the elastic tooth constant. In many heavily loaded gears the total dynamic load may be actually less than the static load determined from the transmitted power. The full static load must be taken by a single pair of teeth when in contact near the pitch point in gears having a contact ratio between one and two. Therefore, the static load may often be used as the maximum load in the design of heavily loaded gears. The fact that initial wear failure usually commences near the centre of the tooth surface substantiates this argument. The report also gives equations predicting total dynamic loads in lightly loaded gear teeth. Here, the term " lightly loaded gear " applies to those gears in which the deflection due to the steady power is very much smaller than the manufacturing error. The dynamic load equations for such gears indicate that the dynamic load varies from a minimum of zero to a maximum value equal to the effective error multiplied by the elastic tooth constant. Simplified equations for dynamic loads in lightly loaded gears in which the effective inertia is due only to the inertia of the gears themselves indicate that the face width of such gears is independent of endurance criteria.

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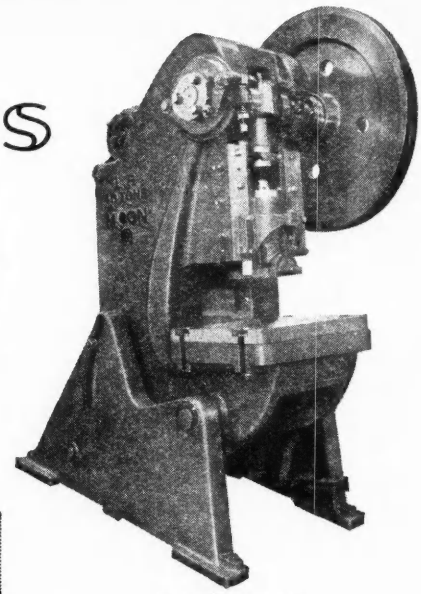

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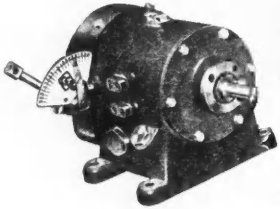

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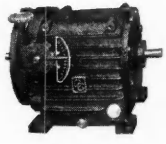

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● *PORTABLE MAGNETIC DRILL PRESS*

A new lightweight portable magnetic drill press, said to have a drilling speed and accuracy equal to that of a conventional drill press, has been developed. This drill press locks in place by means of a powerful magnetic base, which permits the operator to drill at will without physical strain. A control switch with four positions is provided for the magnet. After the drill press has been taken to the work and placed near the spot where a hole is to be drilled, the control switch is placed in the " low " position, closing a circuit which energizes the magnetic base sufficiently to hold it by magnetic force for positioning the drill bit to punch-mark location. The second and third positions of the switch close circuits which energize the electromagnets to the degree required, and in the fourth position a de-magnetizing circuit is closed. A safety feature of the machine is said to be that its base clings securely to the workpiece, even if the electric current is disconnected. Release from the workpiece will be obtained only by closing the de-magnetizing circuit. A built-in lamp serves as a spotlight for locating the drill bit, while a signal light indicates whether or not the base of the press is magnetized. The magnetic-base action is claimed to be sufficiently powerful to withstand a direct pull from 1000 to 2000 lb, according to the size of the unit. Permissible pressures during drilling range from 500 to 1200 lb. The machine is designed to make it possible to drill in locations difficult of access.

● *PHOTOCHEMICAL DEGRADATION OF AUTOMOBILE LACQUERS*

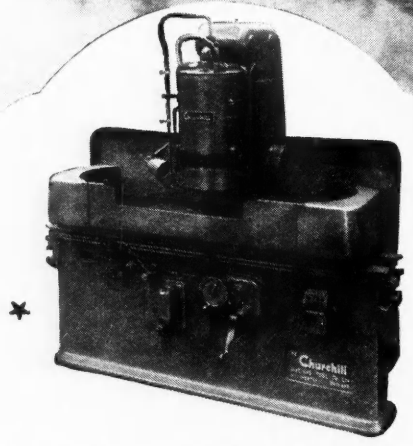
A recent investigation has revealed that, in the weathering of fast-drying automobile lacquers, the only factors contributing to deterioration are sunlight, oxygen, and water vapour or humidity. The relative concentration of each determines the deterioration rate. Without light, no reduction in glossiness occurs. Without oxygen, deterioration is extremely slow. Oxygen without water vapour results in a somewhat more rapid deterioration. The deterioration rate approaches that of natural weather conditions only when all three factors are present. Light not only varies in intensity but also in wavelength. The effect of various colours on the decomposition rate was determined by using a grating monochromator and a high-pressure mercury-arc lamp. Various lacquer panels were exposed to the spectrum, which ranged from the far ultraviolet to the infrared. This work showed that light of longer wavelength than green has little, if any, detectable effect on lacquer decomposition. However, light of a shorter wavelength than green light does deteriorate lacquer. In fact, the shorter the wavelength the greater the deterioration rate becomes. This means that it is not necessary to shield the coating from all wavelengths in sunlight. If a method could be found which removes only the ultraviolet light, very little deterioration would take place. For a number of years various attempts have been made to find materials which, when added to paint vehicles, would absorb the ultraviolet light. However, attempts were unsuccessful, probably because of the extremely short distances in which the ultraviolet light must be absorbed. Light probably penetrates a paint film to about 0·001 in., but the ultraviolet light must be stopped in an appreciably smaller distance for the blockage to be effective. Thus, at present it is not feasible to shield the coating from the weathering factors responsible for its deterioration.

● *RIGID HEAT-RESISTANT POLYETHYLENE*

It is announced that rigid heat-resistant polyethylene will soon be produced in commercial quantities. A higher degree of crystallinity is believed to be primarily responsible for the remarkable properties of these new materials, the new polyethylenes being more than 80% crystalline, as compared with a range of 60 to 65% for the conventional polyethylenes. It is claimed that, as the properties of polyethylene can now be varied over a wide range, the new polyethylenes will not only differ considerably from the conventional types, but will also differ among themselves. Their specific gravity, which reflects their degree of crystallinity, will range from 0·93 to 0·96, compared with 0·92 for the conventional product. It is expected that the new materials will eventually be available as moulding compounds, sheet, film, rods, tubing, and probably also as paper-coating formulations. Softening points range from 240 to 260° F, compared with 210 to 225° F for the most heat-resistant flexible polyethylenes. The rigidity of the new material is claimed to be up to five times that of the conventional polyethylenes. With a tensile strength of 3000 to 3500 psi, the new material almost approaches the tensile properties of vinyls. The bursting strength of rigid polyethylene tubing at 212° F is reported to be about the same as that of ordinary polyethylene tubing at room temperature. The new material is said to have a smooth surface, quite different from the dull waxy surface usually associated with flexible polyethylenes, and a glossy appearance approaching that of polystyrene can be obtained. While rigid polyethylene retains the good dielectric properties of the flexible material, it is no more weather- or flame-resistant than the latter. However, mould shrinkage of the new material is said to be less, while much higher moulding temperatures are required.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

The Gloster JAVELIN
(Photograph by courtesy of The Gloster Aircraft Co. Ltd.)



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